MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. XLIX. FEBRUARY 8, 1889. No. 4

W. H. M. CHRISTIE, M.A., F.R.S., President, in the chair.

William Henry Fisher Alexander, B.A., 26 Bousfield Road, St. Catherine's Park, S.E.;
John Cockburn, 32 St. Andrew Square, Edinburgh;
Thomas Keig, Prospect Hill, Douglas, Isle of Man;
Arthur Courtauld Willoughby Lowe, B.A., Gosfield Hall, Halstead, Essex, and 76 Lancaster Gate, Hyde Park, W.;
Arthur B. P. Mee, Llanelly, Carmarthenshire;
Captain Archibald T. Miller, R.N., H.M.S. *Conway*, Birkenhead; and
Kenneth James Tarrant, Letchford House, Hatch End, Pinner,

were balloted for and duly elected Fellows of the Society.

REPORT OF THE COUNCIL TO THE SIXTY-NINTH ANNUAL GENERAL MEETING OF THE SOCIETY.

The following table shows the progress and present state of the Society:—

	Compounders	Annual Subscribers	Mathematical Society	Total Fellows	Associates	Patron	Grand Total
December 31, 1887	226	365	3	594	48	1	643
Since elected	+8	+19	...	...	...	...	...
Deceased	−7	−7	...	...	−1	...	...
Resigned	...	−12	...	...	...	...	...
Expelled	...	−2	...	...	...	...	...
Removals	+3	−3	...	...	...	...	...
December 31, 1888	230	360	3	593	47	1	641

[The Associate referred to died in 1883, but his death was not known till the present year.]

Mr. Common's Account as Treasurer of the Royal

RECEIPTS.

	£	s.	d.	£	s.	d.
Balances, January 1, 1888:—						
Balance at Bankers', as per pass book ...	327	14	1			
„ on Suspense Account	2	2	0			
„ in hand of Assistant Secretary on account of Turnor and Horrox Funds	5	19	8			
„ in hand of Assistant Secretary on Petty Cash Account	15	4	5			
				351	0	2
Half-year's dividend on £7,500 Consols	109	4	5			
„ „ £5,700 New 3 per Cent. Stock	83	0	2			
Quarterly dividend on £7,500 Consols	54	12	3			
Bonus on conversion of ditto	18	15	0			
Quarterly dividend on £7,500 2¾ per Cent. Stock, late Consols	54	16	11			
Quarterly dividend on £5,700 2¾ per Cent. Stock, late New 3 per Cent.	41	13	8			
Quarterly dividend on £7,500 2¾ per Cent. Stock, late Consols	54	16	11			
Quarterly dividend on £5,700 2¾ per Cent. Stock, late New 3 per Cent.	41	13	8			
Four Quarterly Dividends on £750 Metropolitan 3 per Cent. Stock	21	18	6			
				480	11	6
Received on account of Subscriptions:						
Arrears	212	2	0			
256 Annual Contributions for 1888	537	12	0			
3 „ „ 1889	6	6	0			
29 Admission Fees	60	18	0			
20 First Contributions	30	9	0			
				847	7	0
13 Composition Fees				273	0	0
Sales of Publications:						
At Williams and Norgate's, 1887	7	19	0			
At Society's Rooms, 1888	31	5	6			
				39	4	6
Donation to Lee Fund. Mrs. Jackson Gwilt ...	...		...	5	0	0
				£1,996	3	2

Audited and found correct.

ROBERT BRYANT.
W. B. GIBBS.
THOMAS LEWIS.

Astronomical Society, from January 1 to December 31, 1888.

EXPENDITURE.

	£ s. d.	£ s. d.
Assistant Secretary: Salary	225 0 0	
,, ,, for assistance in editing Society's Publications ...	50 0 0	
		275 0 0
Income Tax and House Duty		11 16 3
Fire Insurance		7 16 6
Printing	565 12 0	
Lithography and Engraving	46 13 6	
Computation of Ephemerides in *Monthly Notices* ...	50 0 0	
		662 5 6
Turnor and Horrox Funds: purchases for Library	17 4 10	
Binding Books in Library	18 18 9	
		36 3 7
House Expenses	35 19 1	
Wages	31 10 0	
Postage, &c.	54 6 11	
Carriage of Parcels	2 6 1	
Stationery and Office Expenses	5 12 5	
Expenses of Meetings	20 0 0	
Coals and Gas	56 1 6	
Installation of Electric Light in Society's Rooms	76 0 0	
Sundry Fittings and Repairs	16 9 5	
Whitewashing, &c.	22 2 0	
Rental of Wire for Time Signal	5 0 0	
Sundries	6 14 1	
		332 1 6
Mrs. Jackson Gwilt's Annuity		8 19 0
Lee Fund Grants		10 0 0
Bankers' Deductions on Cheques	0 2 7	
Cheque Book	0 8 4	
		0 10 11
Balances, December 31, 1888:—		
Balance at Bankers', as per pass book ...	345 19 8	
,, on Deposit Account	300 0 0	
,, in hand of Assistant Secretary on account of Turnor and Horrox Funds	0 14 10	
,, in hand of Assistant Secretary on Petty Cash Account	4 15 5	
		651 9 11
		£1,996 3 2

Assets and Present Property of the Society, January 1, 1889.

	£	s.	d.	£	s.	d.
Balances, December 31, 1888:—						
At Bankers', as per pass book...	345	19	8			
„ on Deposit Account	300	0	0			
Balance in hand of Assistant Secretary on account of Turnor and Horrox Funds	0	14	10			
„ in hand of Assistant Secretary on Petty Cash Account	4	15	5			
				651	9	11
Due on account of Subscriptions:						
13 Contributions of 3 years' standing ...	81	18	0			
27 „ 2 „ ...	113	8	0			
65 „ 1 year's standing ...	136	10	0			
	331	16	0			
Less 3 Contributions paid in advance ...	6	6	0			
				325	10	0
Due from Messrs. Williams and Norgate for sales of Publications during 1888				36	7	1

*£7,500 $2\frac{3}{4}$ per Cent. Stock, late Consols, including the Lee Fund, the Turnor Fund, and the Horrox Memorial Fund.

*£5,700 $2\frac{3}{4}$ per Cent. Stock, late New 3 per Cents., including Mrs. Jackson Gwilt's gift (£300).

£750 Metropolitan 3 per Cent. Stock.

Astronomical and other Manuscripts, Books, Prints, Instruments, and Furniture.

Unsold Publications of the Society.

One Gold Medal.

* The interest that these investments will pay from next April has been reduced by the Chancellor of the Exchequer to $2\frac{3}{4}$ per cent., with a further reduction to $2\frac{1}{2}$ per cent. in twelve years. A bonus of 5*s.* per 100*l* was paid on the conversion of Consols, as appears in the receipts. The payment of interest has been made quarterly, giving in the case of Consols one quarter's extra dividend in this year.

Report of the Auditors.

We have examined the Treasurer's accounts, and have found and certified the same to be correct. The cash in hand on Dec. 31, 1888, including the balance at the bankers', and a sum of 300*l.* on deposit, amounted to 651*l.* 9*s.* 11*d.*

The funded property of the Society is the same as at the end of last year.

The books, instruments, and other effects have been examined, and they appear to be in a satisfactory condition.

We have laid upon the table a list of the names of those Fellows who are in arrear for sums due at the last Annual General Meeting, with the amount due against each Fellow's name.

(Signed) W. B. Gibbs,
Thomas Lewis,
Robert Bryant.

February 8, 1889.

Stock in hand of volumes of the *Memoirs*:—

Vol.	At Society's Rooms	At Williams & Norgate's	Vol.	At Society's Rooms	At Williams & Norgate's
I. Part 1	7	...	XXIX.	410	...
I. Part 2	42	...	XXX.	159	1
II. Part 1	55	...	XXXI.	143	...
II. Part 2	20	...	XXXII.	154	1
III. Part 1	66	1	XXXIII.	164	...
III. Part 2	85	1	XXXIV.	164	4
IV. Part 1	79	3	XXXV.	109	5
IV. Part 2	91	3	XXXVI.	198	8
V.	105	4	XXXVII. Part 1	339	8
VI.	124	3	XXXVII. Part 2	286	8
VII.	148	3	XXXVIII.	274	1
VIII.	127	3	XXXIX. Part 1	246	4
IX.	134	3	XXXIX. Part 2	250	3
X.	145	...	XL.	267	1
XI.	154	...	XLI.	414	1
XII.	159	...	XLII.	236	4
XIII.	163	...	XLIII.	240	1
XIV.	370	2	XLIV.	220	...
XV.	140	...	XLV.	251	1
XVI.	165	...	XLVI.	239	3
XVII.	147	1	XLVII. Part 1	3	...
XVIII.	146	...	XLVII. Part 2	19	...
XIX.	152	...	XLVII. Part 3	2	...
XX.	142	...	XLVII. Part 4	10	...
XXI. Part 1	314	...	XLVII. Part 5	10	...
XXI. Part 2	99	...	XLVII. Part 6	10	...
XXI. 1 & 2 (together)	61	...	XLVII.	219	2
XXII.	164	...	XLVIII. Part 1	264	3
XXIII.	150	...	XLVIII. Part 2	284	1
XXIV.	156	...	XLIX. Part 1	575	7
XXV.	166	...	Index to *Memoirs*	645	...
XXVI.	172	...			
XXVII.	422	...			
XXVIII.	382	...			

Stock in hand of volumes of the *Monthly Notices* :—

Vol.	At Society's Rooms	At Williams & Norgate's	Vol.	At Society's Rooms	At Williams & Norgate's
I.	65	...	XXVI.	10	...
II.	67	...	XXVII.	3	...
III.	...	...	XXVIII.	72	1
IV.	...	...	XXIX.	53	...
V.	...	...	XXX.	66	2
VI.	35	...	XXXI.	96	...
VII.	2	...	XXXII.	118	5
VIII.	138	2	XXXIII.	98	2
IX.	25	3	XXXIV.	77	2
X.	174	1	XXXV.	60	1
XI.	185	1	XXXVI.	32	1
XII.	11	2	XXXVII.	39	3
XIII.	157	3	XXXVIII.	97	2
XIV.	109	3	XXXIX.	108	1
XV.	127	2	XL.	113	3
XVI.	108	2	XLI.	113	5
XVII.	137	1	XLII.	122	1
XVIII.	166	...	XLIII.	122	1
XIX.	58	...	XLIV.	125	4
XX.	34	...	XLV.	126	3
XXI.	17	...	XLVI.	130	3
XXII.	33	...	XLVII.	127	6
XXIII.	19	...	XLVIII.	132	11
XXIV.	24	...	Index to *Monthly Notices*	567	4
XXV.	7	...			

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In addition to the above volumes of the *Monthly Notices*, the Society has a considerable stock of separate numbers of nearly all the volumes. With the exception, however, of Vols. XXXVI. to XLVIII. no complete volumes can be formed from the separate numbers in stock.

Instruments belonging to the Society.

No. 1. The *Harrison* clock.
„ 2. The *Owen* portable circles, by Jones.
„ 3. The *Beaufoy* circle.

No. 4. The *Beaufoy* transit instrument.
„ 5. The *Herschel* 7-foot telescope.
„ 6. The *Greig* universal instrument, by Reichenbach and Ertel. The transit telescope, by Utzschneider and Fraunhofer, of Munich.
„ 7. The *Smeaton* equatoreal.
„ 8. The *Cavendish* apparatus.
„ 9. The 7-foot Gregorian telescope (late Mr. Shearman's).
„ 10. The variation transit instrument (late Mr. Shearman's).
„ 11. The universal quadrat, by Abraham Sharp.
„ 12. The *Fuller* theodolite.
„ 13. The standard scale, by Troughton and Simms.
„ 14. The *Beaufoy* clock, No. 1.
„ 15. The *Beaufoy* clock, No. 2.
„ 16. The *Wollaston* telescope.
„ 17. The *Lee* circle.
„ 18. The *Sharpe* reflecting circle.
„ 19. The *Brisbane* circle.
„ 20. The *Baker* universal equatoreal.
„ 21. The *Reade* transit.
„ 22. The *Matthew* equatoreal, by Cooke.
„ 23. The *Matthew* transit instrument.
„ 24. The *South* transit instrument.
„ 25. A sextant, by Bird (formerly belonging to Captain Cook).
„ 26. A globe showing the precession of the equinoxes.
The *Sheepshanks* collection :—
„ 27. (1) 30-inch transit instrument, by Simms, with level and two iron stands.
„ 28. (2) 6-inch transit theodolite, with circles divided on silver; reading microscopes, both for altitude and azimuth ; cross and siding levels; magnetic needle; plumbline; portable clamping foot and tripod stand.
„ 29. (3) Equatoreal stand and clock movement for $4\frac{6}{10}$-inch telescope (telescope lost) ; double-image micrometer; two wire micrometers; object-glass micrometer.
„ 30. (4) $3\frac{1}{4}$-inch achromatic telescope, with equatoreal stand; double-image micrometer; one terrestrial and three astronomical eyepieces.
„ 31. (5) $2\frac{3}{4}$-inch achromatic telescope, with stand; one terrestrial and three astronomical eyepieces.
„ 33. (7) 2-foot navy telescope.
„ 34. (8) Transit instrument of 45 inches focal length, with iron stand and also Ys for fixing to stone piers; two axis levels.
„ 35. (9) Repeating theodolite, by Ertel, with folding tripod stand.
„ 36. (10) 8-inch pillar sextant, by Troughton, divided

on platinum, with counterpoise stand and artificial horizon.

No. 37. (11) Portable zenith telescope and stand, $2\frac{3}{4}$-inch aperture and 26 inches focal length; 10-inch horizontal circle and 8-inch vertical circle, read to 10″ by two verniers to each circle.

„ 38. (12) 18-inch Borda repeating circle, by Troughton, $2\frac{1}{8}$-inch aperture and 24 inches focal length; the circles divided on silver, the horizontal circle being read by four verniers, and the vertical circle by three verniers, each to 10″.

„ 39. (13) 8-inch vertical repeating circle, with diagonal telescope, by Troughton and Simms; circle divided on silver, reading to 10″; a 5-inch circle at eye-end, reading to single minutes; horizontal circle 9 inches diameter in brass, reading to single minutes.

„ 40. (14) A set of surveying instruments, consisting of a 12-inch theodolite for horizontal angles only, reading to 10″; two sets of adjusting plates; tripod stand with enclosed telescope; heavy stand for theodolite; Y piece of level; two large and three small ground-glass bubbles divided; level collimator, object-glass $1\frac{5}{8}$-inch diameter and 16 inches focal length; micrometer eyepiece, comb, and wires; mercury bottle and trough.

„ 41. (15) Level collimator with object-glass $1\frac{7}{8}$-inch diameter and 16 inches focal length; stand, rider-level, and fittings.

„ 42. (16) 10-inch reflecting circle by Troughton, reading by three verniers to 20″; counterpoise stand; artificial horizon, with mercury; two tripod stands.

„ 43. (17) Hassler's reflecting circle, by Troughton, with counterpoise stand.

„ 44. (18) 6-inch reflecting and repeating circle, by Troughton and Simms, contained in three boxes, two of which form stands. Circle divided on silver, reading to single minutes; two inside arcs divided to single degrees, 150 degrees on each side; artificial horizon and mercury.

„ 45. (19) 5-inch reflecting and repeating circle, by Lenoir, of Paris.

„ 46. (20) Reflecting circle, by Jecker, of Paris, 11 inches in diameter, with one vernier reading to 15″.

„ 47. (21) Box sextant; reflecting plane and level.

„ 48. (22) Prismatic compass, by Troughton and Simms.

„ 49. (23) Mountain barometer.

„ 50. (24) Prismatic compass, by Thomas Jones, mounted with a cylindrical lens.

„ 51. (25) Ordinary $4\frac{1}{2}$-inch compass with needle.

No. 52. (26) Dipping needle, by Robinson.
„ 53. (27) Compass needle, mounted for variation.
„ 54. (28) Magnetic intensity needle, by Meyerstein, of Göttingen; a strongly fitted brass box with heavy magnet; filar suspension.
„ 55. (29) Box of magnetic apparatus.
„ 56. (30) Hassler's reflecting circle, by Troughton; a $10\frac{1}{2}$-inch reflecting and repeating circle, with stand and counterpoise, divided on platinum with two movable and two fixed indices; four verniers reading to 10″.
„ 57. (31) Box sextant and glass plane artificial horizon, by Troughton and Simms.
„ 58. (32) Plane $2\frac{3}{8}$-inch speculum, artificial horizon, and stand.
„ 59. (33) $2\frac{1}{2}$-inch circular level horizon, by Dollond.
„ 60. (34) Artificial horizon, roof, and trough; the trough $8\frac{1}{4}$ by $4\frac{1}{2}$ inches; tripod stand.
„ 61. (35) Set of drawing instruments, consisting of 6-inch circular protractor and common protractor, T-square; one beam compass.
„ 62. (36) A pantograph.
„ 63. (37) A noddy.
„ 64. (38) A small Galilean telescope with object-glass of rock crystal.
„ 65. (39) Five levels.
„ 66. (40) 18-inch celestial globe.
„ 67. (41) Varley stand for telescope.
„ 69. (43) Telescope, with object-glass of rock crystal.
„ 71. Portable altazimuth tripod.
„ 72. Four polarimeters.
„ 74. Registering spectroscope, with one large prism.
„ 76. Two five-prism direct-vision spectroscopes.
„ 78. $9\frac{1}{4}$-inch silvered-glass reflector and stand, by Browning.
„ 79. Spectroscope.
„ 80. A small box, containing three square-headed Nicol's prisms; two Babinet's compensators; two double-image prisms; three Savarts; one positive eyepiece, with Nicol's prism; one dark wedge.
„ 81. A back-staff, or Davis' quadrant.
„ 82. A nocturnal or star dial.
83. An early non-achromatic telescope, of about 3 feet focal length, in oak tube, by Samuel Scatliffe, London.
„ 84. A Hollis observing chair.
„ 85. Double image micrometer, by Troughton and Simms.
„ 86. $4\frac{1}{2}$-inch Gregorian reflecting telescope, by Short, with altazimuth stand and 6-inch altitude and azimuth circles and two eyepieces.

No. 87. $3\frac{1}{4}$-inch Gregorian reflecting telescope with wooden tripod stand.

,, 88. Pendulum with 5-foot brass suspension rod, working on knife edges, by Thomas Jones.

,, 89. A Rhabdological Abacus. A contrivance invented by Mr. H. Goodwyn, consisting of a box filled with compartments, in which are square rods covered with numbers, which can be arranged so as to facilitate the labour of multiplying high numbers.

,, 90. An Arabic celestial globe of bronze, $5\frac{3}{4}$ inches in diameter.

,, 91. Astronomical time watchcase, by Professor Chevallier.

,, 92. 2-foot protractor, with two movable arms, and vernier.

,, 93. Beam compass, in box.

,, 94. 2-foot navigation scale.

,, 95. Stand for testing measures of length.

,, 96. Artificial planet and star, for testing the measurement of a fixed distance at different position-angles.

,, 97. 12-cell Leclanché battery.

,, 98. 2 feet 6 inch navy telescope with object-glass $2\frac{1}{2}$ inches, by Cooke, with portable wooden tripod stand.

,, 99. 12-inch transit instrument, by Fayrer & Son, with level and portable stand.

,, 100. 9-inch transit instrument, with level and iron stand.

,, 101. Small equatoreal sight instrument, by G. Adams, London.

,, 102. Sun-dial, by Troughton.

,, 103. Sun-dial, by Casella.

,, 104. Sun-dial.

,, 105. Box sextant, by Troughton and Simms.

,, 106. Prismatic compass, by Schmalcalder, London.

,, 107. Compass, by C. Earle, Melbourne.

,, 108. Prismatic compass, by Negretti and Zambra.

,, 109. Dipleidoscope, by E. Dent.

,, 110. Abney level, by Elliott.

,, 111. Pocket spectroscope, by Browning.

,, 112. Small brass astrolabe.

,, 113. Double sextant, by Jones.

,, 114. Two models, illustrating the effects of circular motions.

,, 115. A cometarium.

,, 116. A pair of 18-inch globes.

,, 117, 118 } Two old sun-dials.

No. 119. Specimens of diffraction gratings, by Prof. W. A. Rogers.
„ 120. A 6-prism spectroscope, by Browning.
„ 121. Spitta's improved maximum and minimum thermometer.
„ 122. A 6-inch speculum, with flat; the speculum said to be by Sir W. Herschel, and re-figured by Sir J. Herschel.
„ 123. A 6-inch refracting telescope, by Grubb, with 3 eyepieces.
„ 124. Position micrometer, by Cooke.
„ 125. A 6-inch refracting telescope, by Simms, with eyepieces and solar diagonal.
„ 126. $3\frac{1}{2}$-in. portable refracting telescope, by Tulley, with tripod stand (bequeathed by the late Mr. W. H. Bartlett).

The following instruments are lent, during the pleasure of the Council, to the undermentioned persons :—

No. 4. The *Beaufoy* transit instrument, to the Observatory, Kingston, Canada.
„ 22. The *Matthew* equatoreal, to Mr. J. Brett.
„ 23. The *Matthew* transit, to Captain W. Noble.
„ 27. 30-in. transit instrument, with one stand, to Mr. C. Thwaites.
„ 28. (2) 6-inch theodolite and stand, to Mr. A. A. Common.
„ 29. (3) Equatoreal mounting, clock movement, and stand, to Mr. W. Peck.
„ 30. (4) $3\frac{1}{4}$-inch equatoreal and stand, to Mr. E. B. Powell.
„ 34. (8) Transit instrument, to Prof. C. Pritchard.
„ 39. (13) Repeating circle, to Mr. J. N. Lockyer.
„ 42. (16) Reflecting circle and stand, to the Rev. H. P. Slade.
„ 42. (16) Artificial horizon, roof, and mercury bottle, to Mr. C. Thwaites.
„ 69. (43) Telescope, with rock-crystal object-glass, to Dr. W. Huggins.
„ 74. Registering spectroscope, to Mr. J. D. McClure.
„ 76. 5-prism direct-vision spectroscope, to Mr. E. W. Maunder.
„ 108. Prismatic compass, to the Rev. A. Freeman.
„ 123. 6-in. refractor, by Grubb, to the Rev. A. Freeman.

The Gold Medal.

The Council have awarded the Society's Gold Medal to M. Maurice Lœwy for his Equatorial Coudé, his method of determining the constant of aberration, and his other astronomical researches. The President will lay before the Society the grounds upon which the award has been founded.

Obituary.

The Council regret that they have to record the loss by death of the following Fellows during the past year:—

Fellows:—Francis Barrow.
W. H. Bartlett.
Sir C. T. Bright.
J. Rand Capron.
William Cotterell.
Rev. P. A. Fothergill.
Commander J. Ll. Heane.
Rev. R. F. Heath.
Col. A. S. H. Lowe.
Ole Möller.
J. D. Perrins
R. A. Proctor.
J. O. N. Rutter.
James Wigglesworth.

Francis Barrow was born in 1821. He was the only son of the Rev. Francis Barrow, vicar of Cranbrook in Kent. He graduated at Oxford, where he took his B.A. degree in 1841, and his M.A. in 1844. He was called to the Bar at Lincoln's Inn in 1844, and commenced to practise as a special pleader. He went the Home Circuit and was frequently at Cranbrook, where he made the acquaintance of Mr. Dawes, who came to reside there in 1844. This friendship greatly developed his taste for astronomy, and he subsequently erected an observatory of his own at the rear of his house in Phillimore Gardens, Kensington. In 1850 he married Catherine Clara, a daughter of the late Admiral Thomas Dick. He was a Justice of the Peace for the county of Kent, and was appointed Recorder of Rochester in 1867, and in 1876 he was appointed a County Court Judge. He died on September 13, 1888, at his house in Phillimore Gardens.

Mr. Barrow was elected a Fellow of the Society 1870, Nov. 11, and held the office of treasurer from Feb. 1878 to Feb. 1884.

Charles Tilston Bright was born at Wanstead in 1832, and was the youngest son of Mr. Brailsford Bright, of Wanstead.

He was educated at Merchant Taylors' School, and showed special scientific aptitudes very early in life, his attention being particularly directed to chemistry and electricity.

In 1847, at the age of fifteen, he became acquainted with the late Sir William Fothergill Cooke, and was introduced into the service of the Electric Telegraph Company, at that time established to work the patents of Cooke and Wheatstone. From 1847 to 1850 he was connected with the Electric Company, the British Company, and finally with the Amalgamated British and Irish Magnetic Telegraph Company, of which his brother, Edward Bright, had been appointed manager. In 1852 he was appointed engineer to the Company, and at this time he was occupied in carrying out a most extensive scheme of underground wires between London, Manchester, Liverpool, and other places.

Perhaps the first work which brought Charles Bright into public notice was, at the age of nineteen, laying underground the Manchester telegraph lines under the streets of that vast city in one single night without disturbing the traffic.

Charles Bright's connection with the Magnetic Company continued as engineer, and then as consulting engineer, up to the year 1870, when the telegraphs were acquired by the State.

It was during this period that he undertook the great work with which his name is inseparably connected. To mention the Atlantic cable is at once to bring the name of Charles Tilston Bright before us. During the time that the underground system of wires was growing under his hands he was carrying out numerous experiments as to the effects of the transmission of signals through long distances. In his inaugural address in January 1887 to the Society of Telegraph Engineers he says: "Having a great length of underground gutta-percha-covered wire under my control as engineer of the Magnetic Company, I carried out a long series of experiments by having the wires connected up backwards and forwards between London and Manchester so as to form a continuous circuit of a length equal to that of a telegraph cable between Ireland and Newfoundland, or more than 2,000 miles. My method was to use a succession of opposite currents, which I had previously found to be successful with the magneto-electric currents used by that company. I could only try my experiments at night, or on Sundays, when the traffic on the line was small. I showed Professor Morse one night that signals could be sent at the rate of 210, 241, and in one experiment at the rate of 270 signals per minute through that continuous circuit of 2,000 miles of the company's underground wires between London and Manchester. The wires were joined backwards and forwards at Manchester and London, in each loop at both ends a galvanometer being inserted in the circuit to prove that the currents really passed through. By this the resistance, though not the retardation, of the line was largely increased."

The details of laying the Atlantic cable are matters of

history. Suffice it is to say that in carrying out this great work Sir Charles Bright showed himself a man of extraordinary energy and power, rapid in thinking and acting, and endowed with courage and perseverance under difficulties—qualities which enabled him to bring this never-to-be-forgotten undertaking to a successful issue. In recognition of these great services rendered by him to the country and to science, Charles Tilston Bright in the year 1858 received the honour of knighthood at the early age of 26 years.

Sir Charles Bright's subsequent career is closely connected with many great works of telegraph engineering in different parts of the world, which he carried out with the same thoroughness that uniformly distinguished him. It is almost superfluous to mention the numerous instruments and appliances he invented for the improvement of telegraphy, which are well known.

The works he accomplished bear evidence of his skilful handiwork, his intuitive knowledge, and unerring judgment, and as the great fabric of the modern telegraph system rises and spreads throughout the world, its foundations and superstructure bear evidence of the vital part played by him in their construction and formation.

Sir Charles Bright was a Fellow of several learned societies, and was a member of the Institution of Civil Engineers. In 1865 the council of that institution awarded him the Telford Gold Medal. In the same year he was returned to Parliament as member for Greenwich. In 1881 he was appointed one of the British Commissioners at the Paris International Exhibition, and received from the French Government the cross of the Legion of Honour. In 1886 he became President of the Society of Telegraph Engineers and Electricians.

In 1853 Sir Charles Bright married the daughter of the late Mr. John Taylor, of Kingston-upon-Hull, by whom he leaves issue. He was taken suddenly ill while on a visit to his brother, and died of heart disease May 3, 1888.* He was elected a Fellow of this Society 1860, December 14.

John Rand Capron was born in London, February 19, 1829. He was educated at the Grammar School, Guildford, and on completing his studies was articled to his uncle, Mr. John Rand, a solicitor in extensive practice in that town. After being admitted a solicitor, in 1850, Mr. Capron entered into partnership with his uncle, and subsequently succeeded to the business. He was soon appointed Borough Coroner and Clerk of the Peace, which latter appointment he held up to the time of his death.

In the midst of his many business cares and public engagements, Mr. Capron found leisure to gratify his enthusiasm for the study of natural phenomena, and it is as a scientific man of some distinction that his name will be best remembered. When

* Collated by permission from the *Electrical Review.*

at school he had a severe attack of typhoid fever, and during his convalescence a compound microscope was lent to him. This opened out a new world of wonder and beauty, and was the means of firing his ambition to examine some of the fascinating mysteries of creation. He took a special interest in studying the Earth's surface, making considerable progress in geology, and forming a collection of fossils and minerals of great interest and variety. But later on he turned his attention to spectroscopy and meteorological phenomena, and became a devoted student of astronomy.

In 1877 Mr. Capron published an important work on "Photographed Spectra," in which he gave, in a very easy and convenient form for reference, 136 photographs of metallic, gaseous, and other spectra, accompanied by critical explanations. For obtaining the spectra of the metals he employed a direct-vision prism of an inch aperture, with collimator and camera, and with this spectroscope he obtained photographs of the spectra of some forty metals, extending from about *b* to H. For most of these metals two photographs were obtained—one taken with the induction spark, and the other with the electric arc from a battery of 40 pint Grove cells. For the spectra of gases, three different spectroscopes were employed, one of these having two simple quartz prisms of 60°, and the others each a direct-vision prism of large size. The value of this work was fully recognised at the time, as it brought together so many spectra simultaneously before the eye, thus giving a far greater insight into their physical characteristics than could so readily be obtained by a study of the individual spectra with the spectroscope one after the other.

In 1879 Mr. Capron published a popular treatise on "Auroræ and their Spectra." In this work he presented a very complete history of early and recent observations of auroral phenomena, in which he carefully records the general appearance and special characters of auroræ; their geographical distribution; colours, height, and noises attributed to them; phosphorescence, polarisation of their light, &c. The most valuable part of the work is that devoted to an investigation of the spectra of auroræ. The subject is very carefully and exhaustively discussed, and the author's long series of laboratory experiments to elucidate and explain some of the obscure phenomena of auroræ will always be of value in any consideration of the subject. Mr. Capron thus expressed the conclusion at which he arrived from his researches: "As the general result of spectrum work on the aurora up to the present time, we seem to have quite failed in finding any spectrum which, as to position, intensity, and general character of lines, well coincides with that of the aurora. Indeed we may say we do not find any spectrum so nearly allied to portions even of the aurora-spectrum as to lead us to conclude that we have discovered the true nature of one spectrum of the aurora, supposing it to comprise, as some consider, two or more."

In an interesting pamphlet published in 1882, Mr. Capron called particular attention to the subject of the "Rainband," and the importance of observing it as indicative of the presence or otherwise of an excess of moisture in the atmosphere. Among his other scientific papers may be mentioned one on the remarkable auroral beam of November 17, 1882, published in the *Philosophical Magazine*, and the following communications published in the *Monthly Notices*: "Report of Examination of Sun's Disk at Guildford, March 21, 22, 23, 1877, for Suspected Planet *Vulcan*"; "The Partial Eclipse of the Sun, December 31, 1880"; "The Lunar Eclipse, 1881, December 5"; "The *Andromeda* Meteors."

Mr. Capron was a man of the most beneficent and philanthropic character, and took much interest in all the social institutions of his neighbourhood. He subscribed to a large number of charities, and was ever ready, though in the most unostentatious manner, to afford aid and succour to those in poverty and distress.

He had been in failing health for some time past, but his illness took a more serious turn in October, and he passed away on November 12, 1888, at the age of 59 years.

Mr. Rand Capron was elected a Fellow of this Society 1877, March 9, and for five years, from 1883 to 1887, he was a member of the Council.

William Cotterell was one of those few men — whose number, however, may be greater than it seems—who combine the unremitting pursuit of science with the regular occupations of business. The love of physical science, and especially of astronomy, was inbred in him. He inherited it from his grandfather, who, though purely an amateur, made his own telescopes, and acquired instruction by means that would seem meagre in view of the facilities that are now within the reach of everyone. Mr. Cotterell's tastes were thus pronounced from his boyhood. As a youth he was accustomed to take observations of the heavens, which he recorded for himself, making his own star-maps, and diligently working out problems and calculations by methods of his own. Born at Walsall, in Staffordshire, on April 13, 1827, he spent his whole life there, except for a few years' residence in London as a young man. His life was singularly free from incident, except those unobserved incidents which the student is conscious of, and which he remembers as signs of progress or attainment. Though a good citizen, he took no part in public life, otherwise than as being an active member of the Midland Institute at Birmingham, and of the Dudley and Midland Geological and Scientific Society. In connection with those institutions, and more widely—indeed throughout the Midland counties—he was recognised as an authority on the two special subjects to which he had given most attention—namely, astronomy and geology, though his knowledge of the science of

chemistry was also considerable. Loving science wholly for its own sake, he never sought to give publicity to his labours, but they were nevertheless constant. A day seldom passed without some time being given to one or other of the studies that chiefly occupied his thoughts. He left two works in manuscript, which he could not be persuaded to publish. One was a series of dialogues on astronomy; the other he proposed to call "Elements of Physics." Mr. Cotterell died October 23, 1888. He had suffered for some years, at intervals, from bronchitis, and it was an attack of that malady that caused his death. He had at the time made all the necessary arrangements for retiring from business, and had hoped for some years of leisure, which he purposed to devote to his favourite studies, but this pleasant anticipation he was not permitted to realise.

He was elected a Fellow of this Society 1867, December 13.

Percival Alfred Fothergill, late Chaplain and Naval Instructor in the Royal Navy, and Domestic Chaplain to the Earl of Limerick, was the second son of the late Captain Henry Fothergill, 67th Regiment, and was born on July 26, 1830. He was educated at Trinity College, Dublin, where he graduated B.A. In June 1854 he entered the Royal Navy as Naval Instructor and was appointed to H.M.S. *Termagant* (Captain the Hon. Keith Stewart), which formed one of the Baltic squadron under the command of Sir Charles Napier.

Mr. Fothergill was present at the taking of Bomarsund in 1854, being one of the first Englishmen who entered that fort, and he received the Baltic Medal. He subsequently followed Captain Keith Stewart to H.M.S. *Nankin*, and served in China, where he received a medal with two clasps for services at Fatshan and Canton. In 1858 he received a further medal for services in India. For some time he was employed on surveying duty on the coast of Tartary.

In 1859 Mr. Fothergill took Holy Orders, and was subsequently appointed Rector of South Heighton with Tarring Neville, in Sussex. In 1866 he became Vicar of Watford, Northamptonshire, and in 1871 was appointed Rector of South Fambridge, Essex, which living he held to the day of his death, on August 24, 1888.

In 1863 he married the daughter of the late Captain Laugharne, of the Royal Hospital, Greenwich, Senior Captain of the Royal Navy, by whom he leaves issue two sons and three daughters.

Mr. Fothergill was the inventor of "Fothergill's Self-Feathering Screw," which was exhibited at the Exhibition of 1870. He was the author of "Evidence against the Working of the Law in Cases of Sequestration and Dilapidations," and one or two other works.

He was elected a Fellow of this Society 1859, December 9.

Arthur Swann Howard Lowe was the youngest son of the late Alfred Joseph Lowe, J.P. for Nottinghamshire, and was born on December 4, 1826, at Highfield House, in the parish of Lenton, near Nottingham. He received his early education at Mr. Fletcher's school in Nottingham, and with private tutors at home.

In 1852 he entered the Nottinghamshire Militia, and eventually became colonel of that regiment, which he commanded up to the summer of 1887, when failing health compelled him to resign. During this long period of service he took a very active interest in everything that concerned the welfare and satisfactory condition of his regiment.

Colonel Lowe was greatly interested in all scientific pursuits, taking regular meteorological observations and watching astronomical phenomena with much zeal. He rendered material assistance to his brother, Mr. E. J. Lowe, in the preparation of a work on "The Climate of Nottingham." He was an excellent draughtsman, and undertook many illustrations of birds and their eggs. All the drawings of freshwater Mollusca, published in "The Conchology of Nottingham," were made by him.

Colonel Lowe was for many years a Life Member of the British Association, and also a Fellow of the Royal Meteorological Society. He was a magistrate for the county of Essex, and resided at Gosfield Hall, Halstead, where his death took place on August 4, 1888, after some months' illness.

He was elected a Fellow of this Society 1857, January 9.

Ole Peter Möller was born in Denmark on July 22, 1831. He came to England as a youth, and was for more than thirty years a partner in the eminent firm of Galbraith, Pembroke & Co., of Austin Friars. He took a prominent part in all matters relating to sailors, more especially to Scandinavians. He was much interested in the building of the Norwegian Sailors' Church at Rotherhithe. Mr. Möller was also a Director of the Society for the Relief of Foreigners in Distress. In recognition of his services to the Scandinavian section of the Exhibition of 1862, and his ever-ready assistance in all matters relating to Sweden and Norway, H.M. King Oscar created him a Knight of the Order of St. Olaf. Though a lover of science, more especially of astronomy, Mr. Möller did not undertake any active scientific labour.

He was elected a Fellow of this Society 1886, February 12.

James Dyson Perrins was born on November 27, 1823. As a young man he devoted himself to the study of chemistry, and published some researches on the organic base Berberine in the *Journal of the Chemical Society* and the *Annales de Chimie*. Mr. Perrins was early connected with the well-known firm of Messrs. Lea & Perrins at Worcester, with whom he remained an active partner up to the time of his decease. In his time he served in

many capacities in Worcester and the county. In 1860 he was returned to the Council of Worcester; in 1863 he was elected Sheriff, and in the following year became Mayor. Subsequently he was appointed Alderman. In the year 1871 he qualified as a Magistrate for the city, and in 1875 as a Magistrate for the county. In 1874 he was appointed a Severn Commissioner, and in 1885–86 he was elected to fill the position of High Sheriff of the county, a distinction which was evidence of the regard in which he was universally held.

Mr. Perrins took considerable interest in the advancement of the educational institutions in Worcester. He contributed in the most liberal manner to the Victoria Institute, the Public Library, the North Malvern School, and many charitable and useful institutions. The great fortune which fell to his lot was regarded by him as a possession involving commensurate responsibilities, and he was always a generous friend to any movement which expressed the educational and intelligent aspirations of the time. He was a connoisseur in art, and formed a valuable collection of pictures. He was much interested in literature and science, and was well read on many subjects. To this Society he presented a valuable 6-prism automatic spectroscope.

The death of Mr. Perrins, which took place February 26, 1887, leaves a considerable blank in the public and social life of the county of Worcester.

He was elected a Fellow of this Society 1870, May 13.

Richard Anthony Proctor was born in Cheyne Row, Chelsea, on March 23, 1837. He was the youngest of four children, two sons and two daughters, and was rather a delicate child. His mother seems to have been a clever woman. She kept him at home as long as possible, attending to his education herself. His boyish contemporaries remember him as a great reader, devouring books of a more advanced type than boys usually care for. His father, who was a solicitor with literary tastes, died when his little son was thirteen years old.

During later boyhood, Richard Proctor's health improved, and he was sent first to King's College, London, and then to St. John's College, Cambridge, where he obtained a scholarship. While an undergraduate his health still further improved, and he became decidedly athletic. He was captain of the "Lady Somerset," a Johnian Boating Club, and brought his boat up several places on the river.

During his second year at Cambridge he lost his mother, to whom he was devotedly attached; and shortly afterwards, while travelling with his sister, he fell in love with a young Irish lady, to whom he was privately married while at college He came out in the Honours list of 1860 as twenty-third wrangler, a degree which greatly disappointed his friends, many of whom had already recognised his remarkable talent. Feeling unable to fulfil his mother's wish, and enter the Church, he commenced

to look about him for a profession. For a little time he hesitated with regard to the law, and ate dinners at the Temple; but ultimately he decided to devote himself to Astronomy. He lived for short periods first in Ayr, then in Edinburgh, then near Dublin, and afterwards in Devonport.

Mr. Proctor's first literary venture was an article on "Double Stars," which he sent in 1865, without introduction of any kind, to the editor of the *Cornhill Magazine*. He was greatly pleased to find it accepted, and he afterwards used to tell how he was on the point of despatching a letter of warm thanks to the editor for two copies of the magazine containing the article which had been sent him, when a letter arrived enclosing a cheque in payment. His first book was on *Saturn and its System*; it was published in 1865, at his own expense, and occupied him four years in preparation. When it was published it was very favourably received by astronomers, who recognised that a new writer of exceptional ability had appeared. Geometrical conceptions were expounded with great clearness, and astronomical and historical details were explained with an ease and enthusiasm which attracted the reader. But, though the book was well received by the reviewers, the public did not buy it, and he found, to his great disappointment, that its publication was a source of loss instead of profit. This came upon him at a time of great monetary anxiety, for he was a considerable shareholder in a New Zealand bank which failed during the commercial panic of 1866, entirely absorbing his capital. His family was increasing in number, and the grave question pressed upon him whether it was not his duty to forsake Astronomy and devote himself to teaching, or seek an official appointment. He preferred the independent position of an author, and had a great idea of the importance of the calling. By one of those strange coincidences which occasionally occur, he had received from Dr. Henry Lawson, the editor of the *Popular Science Review*, only a day or two before the news of the bank failure reached him, a request to write a couple of articles on "The Telescope," and an unfinished letter was lying on his desk at the time that the news arrived declining the task. The next morning he set to work at the first of the required articles, and, "from that day onward for five years," he says in some meagre notes for an autobiography which he has left, "I did not take one day's holiday from the work which I found essential for my family's maintenance."

It frequently seemed to him that he must give up all idea of continuing scientific work. He says: "I would willingly have turned to stone-breaking on the roads, or any other form of hard and honest but unscientific labour if a modest competence in any such direction had been offered me." Editors of magazines and journals are not always versed in scientific matters, and his articles were continually sent back to him. Even Anthony Trollope wrote to him, on receiving an article on "The Gulf

Stream," that it seemed interesting, but he must ask for some evidence to show that the author was competent to deal with a subject of the kind in a scientific way. Fortunately, Mr. Proctor was able to satisfy him, and the article appeared in due course in the *St. Paul's Magazine*. The publishers were equally shy of his proposed books and star atlases. At the beginning of the struggle he offered to Messrs. Longman, with whom he had published his *Saturn*, his *Handbook of the Stars*, but they would not take it. Then he tried Messrs. Macmillan, but they would not venture. So with the help of a friend 500 copies were printed, which sold and paid expenses. With similar help he brought out his *Constellation Seasons*, drawn by himself in transfer for the stone, and his *Sun Views of the Earth*, produced in the same inexpensive way. Both books paid their expenses and a few pounds over, but no new editions were prepared. At last Messrs. Hardwick engaged him to write a small book called *Half-Hours with the Telescope* for 25*l*. It sold well, and they bought the copyright of him for 25*l*. on each of the first two thousand copies. The book is now in its twentieth edition.

During this period he advertised for pupils in mathematics, and for a time took the position of mathematical teacher with a military coach at Woolwich for young men entering at Woolwich and Sandhurst; but the work was very distasteful to him. Slowly he obtained a footing first with one magazine and then with another. He became a regular contributor of *The Intellectual Observer* (afterwards *The Student*), then of *Chambers' Journal* and the *Popular Science Review*. Book after book was rapidly completed, and was accepted on more or less beneficial terms by publishers.

In 1872 he was elected one of the honorary secretaries of the Royal Astronomical Society, which post he held till November, 1873, when he retired in order to go to America on a lecturing tour. During this period he contributed many important papers to the *Monthly Notices* on "Star Distribution," "The Construction of the Milky Way," "The Distribution of Nebulæ and Star Clusters," and on "The Proper Motions of Stars," etc. These papers, which are illustrated by excellent maps, completely disposed of the artificial theories which had previously been in vogue with respect to the construction of the stellar universe. No doubt some advances had already been made on Sir William Herschel's "flat grindstone" hypothesis with respect to the form of the Milky Way, but Mr. Proctor's papers were the first which graphically showed the results which had been arrived at, and they materially extended the generalisations which may now be said to be universally accepted.

He also communicated to the Society a series of papers on Transits of Venus, in which he examined into the conditions of observation for the Transits of 1874 and 1882 with great thoroughness and at much detail. These papers, like those on

stellar distribution, were very fully illustrated by maps and diagrams.

Amongst other matters with which Mr. Proctor's name will always be associated in the history of Astronomy may be mentioned the accurate determination of the rotation period of the planet Mars. His result, obtained from a careful comparison of drawings dating from 1666 to the present day, is $24^h\ 37^m\ 22^s{\cdot}735$, with a probable error of $0^s{\cdot}005$.

Another piece of original research with which Mr. Proctor's name will probably remain associated is connected with the resisting medium in the lower coronal region, which he definitely showed offers a very appreciable resistance to the upward flight of the matter of solar prominences, when compared with the velocity of a projectile thrown upward in free space under the influence of solar gravity. The paper in which this is shown is contained in the *Monthly Notices*, vol. xxxi. p. 184. Mr. Proctor was an adept in all that refers to methods of projection and map-drawing. One of his greatest undertakings was the charting of the 324,000 stars contained in Argelander's great *Catalogue*, showing the relation of stars down to the eleventh magnitude, with the Milky Way and its subsidiary branches. His energy was almost unbounded. He wrote fifty-seven books, a list of the more important of which is given below. He played with great expression on the piano, and found time for musical practice as well as for chess and whist, both of which games he played extremely well. He wrote on "Luck and Chance," on the "Geometry of Cycloids," on "Mental Phenomena," on "Athletics" and many other subjects.

Mr. Proctor married twice, his first wife having died in 1879, leaving six children. He married again in America, on his return from a lecturing tour in the Australian Colonies, a widow with two young children. Some little time after this marriage he settled in America, and was returning to England from Florida when he was taken ill in New York. The doctors, believing him to be ill of yellow fever, ordered him to be removed from the hotel on a windy and rainy night, and he died within twelve hours of his removal on September 12, 1888.

Mr. Proctor's last and most important work, *Old and New Astronomy*, on which he had been occupied for some years, and to which he had given his best energies, was not finished at his death; but he has left a considerable collection of material for the remaining chapters, and the book will be completed by a friend.

It may certainly be said of Mr. Proctor that he has succeeded in interesting a larger public in the science of astronomy than any other man. His books have been read and his lectures have been listened to not only in England and America, but in most of the English Colonies; and the wide interest he has stirred up in astronomical subjects will no doubt have far-reaching results and bear important fruit.

He was elected a Fellow of this Society 1866, June 8.

A. C. R.

The following are some of the more important works published by Mr. Proctor:—*Saturn and its System* (1865), *Handbook of the Stars* (1866), *The Constellation Seasons* (1867), *Half-Hours with the Telescope* (1868), *Other Worlds than Ours* (1870), *Star Atlas* (1870), *Light Science for Leisure Hours* (1871), *The Sun* (1871), *The Orbs Around Us* (1872), *Essays on Astronomy* (1872), *The Expanse of Heaven* (1873), *The Moon* (1873), *The Borderland of Science* (1873), *The Universe and the Coming Transits* (1874), *The Transit of Venus* (1874), *Our Place among Infinities* (1875), *Myths and Marvels of Astronomy* (1877), *The Universe of Stars* (1878), *Treatise on the Cycloid* (1878), *Flowers of the Sky* (1879), *The Poetry of Astronomy* (1880), *Mysteries of Time and Space* (1883), *The Universe of Suns* (1884), *The Seasons* (1885), *Other Suns than Ours* (1887), *Old and New Astronomy* (1888).

John Obadiah Newell Rutter, who died at Black Rock, Brighton, July 27, 1888, was born in the Isle of Grain, Kent, April 19, 1799. Mr. Rutter was eminently a self-made man. At a very early age his father left England to try his fortunes in the then new colony of New South Wales, where he died in 1806, leaving his son to the care of his uncles and aunts in England, who trained and educated him in such fashion as the opening years of this century afforded. However, in after years he always spoke with gratitude of the kindness shown to him, especially of the motherly care he received at the hands of his aunt Cecilia, who became the wife of the late Dr. Lee, of Hartwell. Learning appears to have come natural to young Rutter, and even at the age of eight years he loved reading, and as years went on he eagerly devoured everything in the way of books brought within his reach. Apprenticeship to a trade followed as a matter of course to one in his position.

As a young man he took to scientific pursuits. He soon acquired a good knowledge of chemistry, and lectured thereon on several occasions. Before 1835 we find him greatly interested in the manufacture of coal-gas, and in the autumn of that year he removed to Brighton to take charge of the Brighton Gas Light and Coke Company. This proved to be the work of his life. From that date until 1882, a period of forty-seven years, his best thoughts were devoted to the service of that company. His own words, in which he desired to record the work of his life, are:—"During fifty years I was engaged, in addition to my other occupations, in promoting the domestic uses of gas. More than half a million of my publications on that subject have been sold."

In addition to chemistry Mr. Rutter devoted himself closely to electricity, upon which subject he gave popular lectures. In 1850 he patented an electric indicator, or fire and thief alarm, and a working model of its adaptation to a house was exhibited in the 1851 Exhibition. In 1854 he published a work on

Human Electricity. For forty years, with but slight intermission, he had one of Alexander Bain's electric clocks at work. As a meteorologist he was most painstaking and diligent in taking observations. As a boy he had knocked about a good deal off the Hampshire coast, and the knowledge then acquired of tides, wind, currents, and nautical matters never forsook him. His fifty-three years' residence in one house at Black Rock gave him a very accurate knowledge of the meteorology of Brighton.

This is not the place in which to record his inner life. We may only say that he was a most charitable man, and as years increased the love of giving increased. He spent a busy, practical, and useful life, with only a brief period of rest. He laid down to die after he had commenced his 90th year.

He was elected a Fellow of this Society, 1835, January 9.

James Wigglesworth was born in 1825, and during the whole of a very busy life had but one recreation, viz. the study of Astronomy. He was an exceedingly careful observer, and had it not been that his health gave way almost immediately after the erection of his large observatory at Scarborough, much good work would have been done there with the assistance of Mr. Lohse, who was engaged by him as observer. Mr. Wigglesworth was on very intimate terms with the late Thomas Cooke, and in 1853 purchased the first 6-inch refractor made by him. This instrument was in use by Mr. Wigglesworth for thirty years. In 1879 Mr. Wigglesworth purchased the Buckingham Works of Messrs. Cooke at York, and that old firm of eminent opticians is now carried on by his son in connection with Messrs. F. and T. Cooke. Mr. Wigglesworth was elected a Fellow of this Society 1885, January 9.

(*Omitted Obituary* for 1883.)

Karl Knorre, the son of Christoph Knorre, Extraordinary Professor of Astronomy in the University of Dorpat, was born in that town $\frac{28 \text{ March}}{9 \text{ April}}$, 1801. In his tenth year he lost his father, whose widow, being left with three children, and in poor circumstances, then went to live with her brother, Karl Senff, who was also a professor in the Dorpat University.

Knorre had from childhood shown great mathematical talent, which rapidly developed under the encouraging instruction of his father into a striking inclination for the exact sciences. This gave him the power even during the lifetime of his father (while yet only eight years old) to perform some minor services in the teaching of mathematics, and after his father's death the boy assisted his mother with the small income derived from the lessons which he gave.

In 1812 Knorre entered the Dorpat Gymnasium, and five years later proceeded to the University, where, in accordance with the wish of his uncle, he commenced the study of theology.

Feeling no inclination for this, however, he soon discontinued it, and gave himself with zeal and pleasure to the private study of mathematics and astronomy, which sciences he had never studied at the University. During the short time that he attended the theological faculty he devoted his nights to astronomical observations in the Observatory. This private study, without any other help than that of his books, says much for his extraordinary talent. At this time the survey of Lirland was undertaken by W. Struve, who selected Knorre as his assistant, thereby giving a new impetus to his studies.

In 1812, on the recommendation of Struve, and by the desire of Admiral Greig, Knorre was appointed Professor of Practical Astronomy at the School of Navigation in Nikolajew. This appointment opened the fairest prospects for the future, as it gave him the direction of an observatory, which was to be built under his superintendence.

The Black Sea fleet was then under the command of Admiral Greig, and to this intelligent and generous man many useful institutions owe their origin, among which the Observatory of Nikolajew takes an honourable place. The tasks set before it were: (1) To satisfy the demands and needs of the marine; (2) to form a centre for the hydrographic operations about to be commenced; (3) to engage in purely scientific work. Knorre devoted himself with zeal and ability to perform these duties allotted to his observatory, and won for it by his labours a worthy position among the observatories of Europe. In 1824, four years after Knorre's entrance upon his duties, Admiral Greig procured for him the means for a two years' scientific journey abroad. Knorre visited the principal observatories and manufactories of astronomical instruments in Germany, England, and France, and became personally acquainted with the heroes of his science. In the summer of 1827 he arrived at Munich at the same time as Bessel, who entrusted to him a portion of the computations for his "Tabulæ Regiomontanæ," which was published at Königsberg in 1830.

He returned to Nikolajew in the autumn of 1827, and entered on his duties in his new, almost completed observatory, which he continued to direct for fifty-one years with uninterrupted devotion and zeal. He was compelled to do everything himself, as he never had an assistant or any other help in his work. At the same time he gave lectures on practical astronomy at the School of Navigation until 1865, when, in consequence of the non-existence of the Black Sea fleet, the institution was closed. Thus all the navigating officers were his former pupils, and not a few of them became able specialists under his tuition. Under his direction and with his co-operation were carried on during thirty years the detailed surveys of the coasts of the Black Sea and the Seas of Azof and Marmora, as well as the straits connecting them and the rivers opening into them. Knorre commenced these surveys personally in the summer of

1822. Later on he gave advice both as to the observations and the carrying out of the work; he determined the formulæ for the computations of the observations, submitted them to strict proof, and calculated many himself. His hydrographic work, however, was not confined to these labours. Admiral Greig, who knew how to value and reward his many-sided ability and mathematical knowledge, employed him to solve and work out various problems relating to shipbuilding, which, though by no means belonging to his branch of study, his comprehensive knowledge enabled him completely to master.

The following is a list of Knorre's printed works:—

1. Der Ort des Polarsterns für jeden Tag der Jahre 1823–30. (Nikolajew, 1824.)
2. Der Ort des Sterns δ *Ursæ minoris* für jeden Tag der Jahre 1823–30. (Nikolajew, 1824.)
3. Sheet 5 of the *Berliner Akademische Sternkarten*, with the Catalogue of Stars. (Berlin, 1835.)

(*In Russian.*)

4. Solution of Triangles. (Nikolajew, 1832.) [In this work plane trigonometry is treated as a special case of spherical. As the sides of a spherical triangle become infinitely small, the formulæ are transformed into those of plane triangles.]
5. Researches on the "Progressika" (Nikolajew 1838). [The "Progressika" is the curve $(n-1)xy^2+ay^2=b^2nx$. It is used in calculations connected with shipbuilding.]
6. Instructions for the Determination of the Altitude of the Pole, Clock Correction, and Instrumental Errors by Gauss's Method. (Nikolajew, 1832.)
7. On the Star Maps, the preparation of which has been undertaken by the Berlin Academy. (Nikolajew, 1836.)
8. Treatise on the work of Prof. Sawitsch, "Anwendung der praktischen Astronomie zu geographischer Ortsbestimmung." (St. Petersburg, 1845.) [For this work Knorre received the Gold Medal of the St. Petersburg Academy.]
9. Exposition of Bessel's Method of Clearing Lunar Distances. (Nikolajew, 1837.)
10. Determination of the Error of Collimation of the Mirror in Magnetic Theodolites. (Nikolajew, 1869.)
11. Lectures on Practical Astronomy, given in the School of Navigation of the Black Sea Fleet.

Besides these works, he was the author of many contributions to Schumacher's *Astronomische Nachrichten*, and Demidoff's "Voyage dans la Russie Méridionale et la Crimée"; also of

many years' magnetical and meteorological observations in Kupper's "Sammlungen," and of many smaller papers and translations. He furnished yearly, without remuneration, the astronomical part of the almanacs published in Odessa and Tiflis, besides lesser contributions to these works. There also deserves to be mentioned his improvement in sextants, consisting in the placing of a level upon the alhidade. By this arrangement the identification of a star observed in a mercurial horizon with the image reflected from the mirror is considerably facilitated (*Astron. Nachr.*, Band 7, p. 262).

The most important work of Knorre's was sheet 5 of the *Berliner Akademische Sternkarten*. It was chiefly the accuracy and completeness of this sheet that inspired a zealous lover of astronomy, the late Secretary Hencke, of Driesen, with the idea that the continued comparison of this map with the heavens must lead to the discovery of new planets. Hencke's perseverance was rewarded on December 8, 1845, by the discovery of *Astræa*. This brilliant success made a great impression on the scientific world, and at once engaged many young astronomers in similar researches. On July 1, 1847, Hencke succeeded in discovering another planet, *Hebe*, and this was followed, on August 13 of the same year, by the discovery of *Iris* by Mr. Hind. Since then so many minor planets have been found, that the number of discoveries yet to be made can no longer be reckoned. When astronomical history records these discoveries it will be acknowledged that Knorre's map gave the first impulse to this enrichment of our knowledge of the Solar System, so far surpassing all expectations.

Thus he lived and worked during half a century, in a great measure cut off from cultivated scientific society, and depending almost entirely on himself and his books. He often felt this keenly, although otherwise contented with his respected and independent position.

After the conclusion of the Crimean war Nikolajew, which, on account of its admiralty and observatory, as well as being the seat of administration, had the charge of attending to the wants of the Black Sea fleet, lost its special function. The observatory also obviously lost the object of its existence, and its high position was reduced by this sudden change. The blow which followed the Treaty of Paris in 1856 seemed the more crushing, in that Greig's creations in Nikolajew had been so promising and important for the future, and so significant in their successes. Knorre was filled with sorrow and anxiety; his hopes for the future of his observatory were destroyed; yet he was by no means disheartened, and did not relax his energies. With continued ardour and zeal he carried on his usual duties, besides his scientific labours, though in the latter he was greatly hindered by the unfavourable circumstances resulting from the catastrophe already mentioned. The observatory, which had been an attribute of the marine, suffered the loss of its position

and significance, and sank into the background. It was now little regarded, and was deprived of the means for performing various tasks, and particularly of the means for purchasing new astronomical instruments which were necessary to Knorre for his observations and studies. As a scientific institution it was only the European fame and highly-esteemed personality of its director that preserved for the observatory its honourable position and continued existence. In order to duly appreciate its achievements these unfavourable circumstances must always be taken into account. In this manner, and in the midst of these discouraging surroundings, Knorre performed his duties in the observatory which had become so dear to him for fifteen years longer, till the summer of 1871. A man of seventy, he now longed for repose, and in August 1871 he resigned his position, retiring from the service with the rank of a "Geheimrath." In September he left with his family for Berlin, where he spent the evening of his life in rest and retirement. After a period of twelve years, which he passed in happiness and contentment in the midst of his family, he passed peacefully away on September 10, 1883, in the 83rd year of his life.

From his great talents and wide knowledge, as well in the exact as in other sciences, Knorre was an authority not only in naval circles and in those of his scientific friends, but also among the intelligent inhabitants of Nikolajew, who highly valued his opinion and advice, which were given with kindliness and courtesy to all who came to him for instruction and information. Through the nobility of his character and his generous views he won universal respect and sympathy from all who knew him.

Professor Knorre was elected an Associate of this Society 1848, May 12.

Proceedings of Observatories.

The following Reports of the proceedings of Observatories during the past year have been received from the Directors of the several Observatories, who are alone responsible for the same.

Royal Observatory, Greenwich.

At the beginning of the year 1888 the Y's of the transit-circle were taken out, thoroughly cleaned, and readjusted so as to correct the large level and azimuth errors which had gradually developed, a sheet of tinfoil being placed under the western Y. From a recent discussion of these errors (*Monthly Notices*, 1887, vol. xlvii., p. 325) it appears that each is subject to changes in course of years: the level error has had in recent years a tendency to become negative; that is, the eastern pivot is now rising relatively to the western, though in the years 1851–1870 the contrary tendency was noticed. For the year 1887 the mean value was distinctly negative, the extreme values being $-10''\cdot2$ on June 15 and $-1''\cdot2$ on October 12. By the operations in 1888, January, this error was advisedly over-corrected, so that the mean level error is now positive. The extreme values in 1888 were $+7''\cdot0$ on January 17 and $-2''\cdot0$ on August 10.

The azimuth has recently shown a change in the positive direction; that is, the eastern pivot has been moving relatively north, though in the period 1851–1870 it was comparatively steady. The extreme values in 1887 being $+15''\cdot9$ on August 31 and $+2''\cdot8$ on April 14, this error was also over-corrected, so that the extreme values in 1888 were $-8''\cdot2$ on April 7 and $+3''\cdot3$ on September 27 and October 26. The mean level error is thus $+2''\cdot5$, and the mean azimuth error $-2''\cdot5$.

The regular meridian work has been carried on as before throughout the year 1888. The number of transits observed was 5,186, and of zenith distances 4,979; the total number of stars observed in the year being 1,816. Of stars for special purposes, 106 observations have been made in all of the 28 comparison stars used by Dr. Gill for the opposition of *Iris*, the planet herself having been observed with the transit-circle on eighteen nights. Stars used in the determination of the longi-

tude Paris-Greenwich have also been put on the working list, and 45 stars with remarkable spectra.

The mean error in R.A. of Hansen's lunar tables with Professor Newcomb's corrections, as deduced from 79 observations with the transit-circle in 1888, is $+0^{s}\cdot079$, showing a slight increase on the mean for 1887, $+0^{s}\cdot068$, which was itself an advance on the steady value of $+0^{s}\cdot03$ found from observations in the years 1883–1886. The comparatively small number of observations in 1888 is an indication of the bad weather in the summer, only three meridian observations of the Moon having been made in June, and only five in July, though the corresponding numbers for 1887 were thirteen and fourteen respectively.

Observations of the horizontal flexure of the transit-circle by means of the collimators on 1888, February 29, April 10, April 12, and 1889, January 3, gave $-0''\cdot11$, $+0''\cdot28$, $+0''\cdot13$, and $+0''\cdot08$; agreeing with the results of recent years in indicating that the horizontal flexure is sensibly zero.

The apparent correction to the nadir observation deduced from reflection observations of stars in 1888 is $-0''\cdot118$, the numerically largest value for any month being $-0''\cdot43$ for the month of May (20 nights). No correction for this discordance has been applied.

In 1879 observations were made in the months of May and June on the distribution of temperature in the transit-circle room, thermometers being placed at selected points; but the investigation was not carried further when it became evident that there was no serious anomaly in the gradual diminution of temperature outwards from the instrument. It has recently seemed desirable to make a more complete investigation, and three thermometers mounted in the middle and at the north and south angles of the horizontal shutter opening have been regularly read in 1888, with the three thermometers ordinarily in use. So far, the observations seem to show that the temperature at night falls off more rapidly towards the south than towards the north, and that the surfaces of equal temperature tend to follow the angular shape of the room. The observations will be continued in 1889.

A proposal having been made for the construction of a new line of railway in a tunnel across Blackheath (in extension of the authorised Bexley Heath Railway), some experiments were made in March and April on the disturbance caused by existing railways. One observer at the transit-circle noted the times of all disturbances of the image of the wires as seen by reflection from the surface of mercury, while other observers travelling on the trains or taking up positions at railway stations noted quite independently the positions and movements of all trains as far as was possible. On comparing the two lists of observations it became apparent that tremors were caused by trains up to a distance of one mile at least, the disturbance becoming so great at shorter

distances as to make the reflected image invisible, and being increased by passage of the trains through tunnels.

Owing to pressure of other work the personal equation machine has not been used in the past year.

The current reductions have been kept up to date by rather special efforts, in view of the heavy work requisite for the forthcoming "Ten-Year Catalogue."

The straightforward reductions for the "Ten-Year Catalogue" are practically completed; there remains, however, the examination of discordances and the correction of errors. Besides the accidental errors a list has been prepared of cases where the thermometer was not read sufficiently near the observation of a star, and where a correction to the adopted reading may be advantageously inferred from the photographic registers of the meteorological department. This piece of work has in itself involved considerable time and labour, though the final corrections to N.P.D. will in general be small; but the importance of the catalogue for comparison with "Stone's 1880 Cape Catalogue" and others, and the consequent investigation of refraction, has made it imperative that the greatest care should be taken to have accurate thermometer readings.

As regards discussions to accompany the catalogue, the meridian observations of the Sun from 1877–1886 have been reduced to a uniform system and discussed for correction to epoch, which has been found insensible.

The mean places of clock stars as found from groups of at least twelve hours' observation by the same observer have been compared with the catalogue places (which depend on all groups of more than six hours): the differences are almost insensible, the largest being $0^{s}\cdot007$ in the neighbourhood of 23^{h} R.A. In the case of the Nine-Year Catalogue (1872) the differences were more pronounced. It appears, therefore, that a distinct advance has been made towards eliminating the systematic errors of the R.A.'s of clock stars. The list of Mean R.A.'s of clock stars for 1889 already distributed to observatories is based on the 12-hour groups of the period 1877–1886.

The altazimuth observations of the Moon in the first and last quarters have been continued as before. The erection of a new photographic dome at the end of 1887 made it necessary to discontinue the observations of the collimator and of the mark on the Royal Naval College, which is now hidden by the new building, and during the last year the adjustments of the instrument have depended on observations of high and low stars. An opening has now been cut in the cornice of the altazimuth building to allow of a view of two distant church spires which since 1888, November 26, have been regularly observed as marks when visible, and also of a nearer church spire at a distance of 355 yards, which will be available for observation in foggy weather by means of a long-focus lens, now nearly completed.

Comet *a* 1888 (Sawerthal) was observed on 23 nights, and

Comet *e* 1888 (Barnard) on five nights, with one or other of the equatorials. Comet *e* 1888 has also been observed on eight nights with the transit-circle.

Ten disappearances and nine reappearances of stars occulted by the Moon have been observed, these numbers including six disappearances and eight reappearances on the occasion of the total eclipse of the Moon, 1888, January 28, to which reference was made in the last report. Fourteen phenomena of *Jupiter's* satellites have also been observed. The smallness of all these numbers is again due in some measure to the unfavourable weather.

The provision of a photographic telescope of 13 inches aperture with a 10-inch guiding telescope, to enable this Observatory to take part in the Photographic Map of the Heavens, was sanctioned by the Treasury at the end of August, and the construction of the instrument has been entrusted to Sir Howard Grubb. A number of photographs of stars were taken last summer with a 6-inch object glass made by Sir Howard Grubb, as an experiment preliminary to the construction of the 13-inch object-glass intended for work on the Photographic Chart; but the results are inconclusive, as it was found that one of the pieces of tinfoil between the lenses was missing, and that consequently the object-glass was not properly adjusted. The glass is now in Sir Howard Grubb's hands for slight modification previous to re-examination at this Observatory.

About twenty photographs were taken in June and July to demonstrate the practicability of transferring stellar images from the curved plates, of which mention was made in the last report, to flat plates, where they can be more readily measured with a micrometer. For this purpose, the Dallmeyer lens, with which the plates were originally taken, was mounted about the middle of a wooden tube 20 feet long (four times the focal length), and stopped down to two inches to diminish aberration. The curved original and the flat plate to receive the copy were placed at ends of the tube, diffused daylight being used in these operations. The results appear to be satisfactory, and indicate that the curved plate gives a flat field at the conjugate focus, as was expected.

Further micrometric measurements of the flat plates obtained with the Dallmeyer objective have confirmed the conclusion that star places can be obtained with sufficient accuracy over a field 4° square, for which the images are nearly round, and even outside this limit where the images become crosses or ellipses. In one case the places of 47 stars on the plate as photographed at three positions for focus, differing by 0·16 inch, or about one four hundredth of the focal length, were measured, to determine the effect of a change of focal length, when the exposure remains the same. In another instance two exposures (of 20^m and 5^m) were taken at the standard focal reading, and a similar pair at a reading differing by 0·10 inch; and the places

of each of 30 stars compared in the four cases. The results indicate that the places obtained are independent of a considerable change in focal length (allowance being made for change of scale), and of a considerable difference in exposure.

A satisfactory pair of discs for the 28-inch object-glass has at length been obtained from Messrs. Chance, and Sir Howard Grubb expects to have the object-glass completed by next October.

Observations with the half-prism spectroscope for the determination of the motions of stars in the line of sight were intermitted from the end of May until December, during which interval the single-prism spectroscope was used to examine the spectra of *α Herculis*, *β Lyræ*, *γ Cassiopeiæ*, *P Cygni*, *R Cygni*, *β Pegasi* and *Mira Ceti*. The spectrum of Comet Sawerthal was observed on three nights, and that of Comet Barnard on one. For determination of motion of stars in the line of sight, 106 measures of displacement of the F line have been obtained from the spectra of 26 stars, besides 25 measures of lines in the spectra of the Sun, Moon, or planets as a check on the adjustment of the instrument and general accuracy of the measures.

Attempts have been made to photograph the spectra of stars with the south-east equatorial. Some photographs of the spectrum of *Vega* have been obtained.

With the photo-heliograph, photographs of the Sun have been taken on 195 days, and 380 selected for preservation, including ten photographs with a double image of the Sun taken to determine the position of the wires with reference to a declination-circle. The additional photographs received from India and Mauritius leave only six days in the year ending 1888, November 16, on which no photograph is as yet available for measurement.

One hundred and eighteen photographs taken at Harvard College, Cambridge, U.S., between the dates 1874, December 9 and 1875, August 31, have been received from the Solar Physics Committee; of these 55 have been measured and reduced to fill up gaps in the Greenwich Series.

Ten photographs taken at Ely, between the dates 1874, January 1 and February 15, have also been received.

In 1885 a series of measures was made of a set of 8-inch photographs for the determination of the probable error of a single measure of distance, position-angle, and area. During the past year a corresponding series has been made on 4-inch photographs, and on comparison of the two it is found that measures of distance and position-angle are about twice as accurate with 8-inch pictures, the magnification having its full advantage; but that measures of area are not sensibly more accurate with 8-inch than with 4-inch pictures, the gain by magnification being apparently counterbalanced by loss in definition

In the period September 23 to November 15 observations were made in concert with French officers of the Service Géographique de l'Armée to re-determine the longitude Paris-Greenwich. A previous determination of this longitude in 1854 by M. Faye and Mr. Dunkin, using eye-and-ear methods both for star observing and signals, gave a value which appears to be about $0^{s}.5$ too small on comparison with subsequent observations, more or less indirect, although the accordance of the separate nights among themselves was excellent, and indicated a result which might be accepted with some confidence. It was therefore a matter of importance to re-determine this longitude with modern instrumental improvements and by several observers. A wire was kindly put at the disposal of the Observatory by the Submarine Telegraph Company for the requisite period, and arrangements were made by the Post Office Telegraphs for direct communication with Paris. Observations were made in four groups of three full nights each (or the equivalent in half-nights). An English and a French observer were stationed at each end, each with a separate instrument and chronograph, and the pairs of observers were interchanged twice. The pairs of English and French instruments were similar, and the chronographic method was used both for recording star transits and signals. On a full night each observer recorded about forty star transits, reversing his instrument three times, and exchanged signals twice (near the beginning and the end of the evening) with his compatriot at the other end of the line, and once with the other observer. The actual stations were the front court of the Royal Observatory (in the meridian of Bradley's transit, and a few feet only from that of the transit-circle) and the Observatory of the Service Géographique at Paris, whose position with respect to the Paris Observatory has been accurately determined. Commandants Bassot and Defforges were the French observers, and Mr. Turner and Mr. Lewis the English.

While stationed at Greenwich Commandant Defforges took the opportunity of swinging his reversible pendulums, to determine the absolute force of gravity. The Indian invariable pendulum has recently been mounted under General Walker's supervision in the Record Room at Greenwich for observations similar to those already made in India and at Kew. By these two operations the French and Indian pendulum determinations will be connected through Greenwich.

The enlargement of the computing-rooms referred to in the last report was completed in April, and the new 18-feet dome has been built over them. No instrument has as yet been mounted there, the intention being to reserve the site for the new photographic refractor.

The volume of Greenwich *Observations* for 1886 and the *Spectroscopic and Photographic Results* for 1887 were distributed last September, and the printing of other results in 1887 is well advanced.

Royal Observatory, Edinburgh.

On August 15, 1888, Professor C. Piazzi Smyth resigned the posts of Astronomer Royal for Scotland and Professor of Practical Astronomy in the University of Edinburgh, which he had held for forty-three years. On January 29, 1889, Her Majesty was graciously pleased to appoint Ralph Copeland, Ph.D., to succeed Professor Smyth in the double capacity. In the interim the charge of the Observatory devolved upon Mr. Thomas Heath, First Assistant Astronomer, who, with the aid of Mr. James Forgan, acting Second Assistant Astronomer, has carried on the reductions and observations unremittingly and most efficiently up to the present time. These have consisted of:—

(*a*) The computation of the monthly schedules of the twice-a-day observations at fifty-five of the stations of the Scottish Meteorological Society, and their comparison with the means of the last thirty-two years, for the use of the Registrar-General, who has published them in his printed reports.

(*b*) Observations of the barometer and three thermometers in different exposures, recorded with the usual weather-notes at 1 P.M.

(*c*) Weekly readings of the rock thermometers at depths of 21 feet, 10 feet, 4 feet, and 2 feet, as detailed in Professor Smyth's final report to Her Majesty's Secretary for Scotland. On June 30, 1888, two essays were completed at the Observatory and communicated to the Royal Society of Edinburgh, in addition to the one on the 24-inch equatorial reflector mentioned in last year's report; they are:—"Mean Scottish Meteorology for the last Thirty-two Years," and "Eight Years' Observations of the New Earth Thermometers." The first-mentioned paper contains thirty-one tables of monthly and annual mean results of Scottish meteorology, with fourteen plates of curves. The paper on the earth thermometers contains four tables, with three supplementary tables and four plates of curves.

These two papers have been printed and published by the Royal Society of Edinburgh, the proofs having been, for the most part, revised at the Observatory, and posted to Professor Smyth for final examination before going to press.

The whole of the buildings and instruments are in a condition similar to that in which they were at the above-mentioned date. No alterations or improvements have been made, with the exception of a complete re-painting of the outside wood-work and the dome of the Observatory, and a much-needed new arrangement for the water supply at the First Assistant's residence, carried out in the autumn by W. W. Robertson, Esq., of H.M. Office of Works.

Considering the present condition of the Observatory, no

new scientific work has been undertaken, but the usual observations of clock stars, and occasionally of the Sun when necessary, with the transit instrument, have been regularly carried out for the purposes of the daily signalling by time-ball, time-gun, and electrically controlled clocks. All the instruments connected with these duties are in a state of complete efficiency. No official appointment to the post of Second Assistant Astronomer has been made since the resignation of Mr. H. W. Ride in February 1888, but, in order to carry on the work of the Observatory, Mr. Heath has been allowed to engage Mr. Forgan's services as temporary Second Assistant, and arrangements have been made by the Exchequer Office for the payment of his salary. In consequence of the assiduous attention which Mr. Forgan has devoted to his duties at the Observatory, this plan has worked in every way satisfactorily.

The original drafts of the MSS. of the unprinted Spectroscopic volume, prepared with so great expenditure of labour by Professor Smyth, still remain deposited in the computing room of the Observatory, the printer's copies being in Professor Smyth's care at his residence.

In the autumn of 1888 the Lords Commissioners of Her Majesty's Treasury accepted the princely gift made to the nation by the Earl of Crawford and Balcarres of the whole of the instruments and equipment of the Dunecht Observatory, for the better outfitting of a new royal observatory, to be built and maintained on a suitable site near Edinburgh. The value of this gift may be gathered from the following abstract of the Dunecht inventory:—

	Number of pieces.
A. Telescopes	16
Including the 15-inch equatorial and the 8·6-inch transit-circle.	
B. Telescope accessories	25
C. Domes, huts, &c.	9
Amongst these are several huts well suited for field work.	
D. Stands, piers, and furniture	57
E. Clocks and chronometers	19
Of these two are compensated clocks, and six are first-class box-chronometers.	
F. Thermometers and barometers	32
Including the King's barograph.	

G. Optical apparatus in seven divisions :—

	Number of pieces.
a. Lenses	13
b. Mirrors	4
c. Diffraction apparatus	8
d. Special objects made of quartz	7
e. Prisms	24
f. Polarising apparatus	10
g. General optical appliances	21
	87

Many of these numbers represent complete groups of apparatus for special studies; e.g. in *c.* is a set of the contrivances devised by Schwerd for his classical researches on diffraction.

H. Photographic apparatus	28
I. Electrical and magnetical apparatus	68
J. Small instruments and miscellaneous appliances	61
K Spectroscopes and accessories	22
L. Measuring bars, &c.	16
M. Tools and materials	37

N. Library of upwards of 15,000 printed books and pamphlets, MSS., engravings, &c.

The printed catalogue of books and pamphlets extends to 485 pp. of two columns, in 4to. A list of the MSS. is being prepared for the press.

When to this admirable collection is added the 2-foot silver-on-glass reflector now at Calton Hill, which it is hoped may be remodelled on the lines devised by Professor Piazzi Smyth, Scotland will possess the instrumental outfit of a first-class national observatory.

The broken nature of the ground around Edinburgh gives considerable scope in the choice of a favourable site for the new observatory, and negotiations have for some time been in progress for securing a desirable piece of ground about three miles from the heart of the city. Respecting the proposed new buildings, it can only be said at present that the 22-foot dome now at Dunecht will be re-erected for the relatively short 24-inch reflector, while a new and larger dome will be provided for the 15-inch equatorial; and that a new meridian house of iron and wood, designed to afford the most perfect ventilation, will cover the transit-circle and its collimators. The fact that the new buildings will be constructed by H.M. Office of Works is an ample guarantee that they will be satisfactory in every respect.

With the erection of the new Royal Observatory, thus to be

brought about by the munificence of Lord Crawford, it is hoped that a vigorous impetus will be given to the study of astronomy in Edinburgh, and that arrangements may be devised by which students will have every facility for becoming acquainted with the practical details of observational astronomy as well as the fundamental principles of the science.

The present Royal Observatory was visited on October 10 by a committee of several members of the Edinburgh Town Council, headed by Lord Provost Sir Thomas Clark, Bart., for the purpose of examining the buildings and instruments in view of the offer made by H.M. Government to transfer the buildings and certain of the instruments to the town on the completion of the new Observatory buildings.

A similar visit was made on October 26 by Lord McLaren, Professor P. G. Tait, and W. W. Robertson, Esq., to examine and value the instruments on behalf of the Exchequer, for the purpose of the proposed transfer.

Royal Observatory, Cape of Good Hope.

During a great part of the year 1888 the weather was exceptionally unfavourable for astronomical work. The rainfall at the Observatory was 36·06 inches, as compared with 23·08 inches in 1887, and with 24·81, the mean of forty-two years. This was accompanied by a still greater percentage increase of cloud, especially during the period April to October. Observations with the transit-circle have been continued regularly throughout the year. The chief objects of observation have been the Sun, *Mercury*, and *Venus*, stars in the list of the Cape 10-year catalogue for 1890, comet comparison stars, stars occulted by the Moon, stars employed in the latitude and longitude determinations of the geodetic survey of South Africa, and stars employed in zones for determining the scale-value of the heliometer. In addition, the minor planet *Iris* and the selected comparison stars were regularly observed between October 12 and December 13.

The work accomplished in 1888 has been as follows :—

Number of determinations of collimation	52
„ „ level	372
„ „ nadir	383
„ „ runs	378
„ „ flexure	64
Number of observations of meridian mark	374

	Direct.	Reflex.
Number of observations of stars in R.A.	4947	156
„ „ „ N.P.D.	4576	155
Observations of both limbs of the Sun in both elements	118	
Observations of *Mercury*	64	
„ *Venus*	90	
„ *Iris*	32	

The work with the great theodolite has been limited, from the want of an available assistant, no observing computer having been available for any kind of observing during the year, and the services of Mr. Pett having been devoted to the zenith telescope. Thus there have only been observed with the theodolite—

Azimuths of pairs of N. stars for latitude (Kapteyn's method)	12
Observations of azimuth marks	2
Determinations of runs	4

With the zenith telescope 849 pairs of stars have been observed by Talcott's (Horrebow's) method, partly in connection with Kapteyn's method of latitude determination, partly for control on the law of flexure of the transit-circle, and for the connection of the northern and southern systems of declination.

The following occultations of stars by the Moon have been observed :—

Disappearance at bright limb		0
Reappearance at bright limb		1
Disappearance at dark limb		18
Reappearance at dark limb		8
During Total Eclipse of Moon, 1888, January 28	Disappearance	11
	Reappearance	11
	Total	49

On February 18, in the early morning, a comet was detected in the constellation *Telescopium*, by Mr. H. Sawerthal, whilst he was engaged in exposing photographic plates in connection with the work of the southern *Durchmusterung*. The comet was observed with the equatorial by Mr. Finlay on seventeen mornings, and by Dr. Gill with the heliometer on five mornings, between February 18 and March 17 inclusive. The Warner prize of 100*l.* has been awarded to Mr. Sawerthal for his discovery.

Photographs of the comet were obtained on February 20, 24, March 9, 12, 13, 17, which will be presented to the Society, together with definitive results of the observations.

From the progress made in the early part of the year by the constant employment of two observers, it was anticipated that the photographic work of the *Durchmusterung* would be completed early in 1889, but the exceptionally clouded state of the sky in the months of April, May, and June made it impossible to complete the photography of the zones which culminate at night during these months.

During the year 885 plates have been exposed—

17 in attempts to photograph ℳ Sawerthal,
746 passed for measurement in connection with the *Durchmusterung*,
110 deficient on account of haze, cloud, or fogging of the object-glass,
12 useless and entirely rejected.

Total 885

The measurement of the plates is being rapidly and successfully pushed forward by Professor J. C. Kapteyn. The photographic part of the work will probably be completed in June 1889, and it is confidently anticipated that the complete *Durchmusterung* will be ready for press within three years.

The progress of working with the heliometer was at first greatly delayed by the inconvenience and inefficiency of ordinary batteries as a source of electric light for its illumination. By the liberality of the Lords Commissioners of the Admiralty, provision was made for an efficient dynamo capable of supplying electric light not only for all the instruments and offices but for the houses of H.M.'s Astronomer and Chief Assistant also (the latter houses form part of the main observatory building). The necessary plant for carrying out the illumination of the observatories, instruments, and computing-rooms was sent out early in February, and was completely installed and at work before the end of the month. Every separate observatory has now its own group of accumulators, each observatory and each instrument is illuminated by the electric light; and the immense advantages of this light for astronomical purposes can only be fully appreciated by those who have practically experienced it.

In each of the detached observatories six-volt lamps are employed, supplied by three cells of 350 ampere-hours capacity. In the main building, including the library, computing-rooms, and transit-circle, a group of twelve cells of similar capacity is used, with lamps of twenty-four volts. The whole of the accumulator groups in the various observatories are charged *in situ*, in series, once a week, each group being switched out as it becomes fully charged, so that there is no waste of energy from undue overcharging. The system has been entirely successful, and has worked without trouble or failure of any kind since its installation.

Previous to the definitive installation of the electric light regular work with the heliometer could not be efficiently under-

taken. A large number of observations of scale-value zones, &c., were made, and many necessary preliminary investigations and experiments were carried out.

Regular researches on stellar parallax were begun in the end of February. Considerable difficulty was found in arranging a programme such that, on the one hand, as little time as possible should be lost, and, on the other hand, that its full execution should not clash with the heliometer observations of *Iris* in the mornings of October, November, and December 1888, or with the observations of *Victoria* and *Sappho* planned for June, July, August, September, October, November, and part of December 1889. A further difficulty was created by the exceptionally cloudy weather of April, May and June, which defeated the intended commencement of some additional series. The following stars have been observed for parallax by Dr. Gill with one pair of comparison stars each, at each of two periods of maximum parallactic displacement in distance, and generally with six nights' observations at each period :—

β Hydri	*Sirius*	*β Centauri*
α Eridani	*β Crucis*	*α Gruis*
β Orionis	*α Virginis*	*Fomalhaut*
Canopus.		

The third period of maximum displacement for each of these pairs can be observed without interfering with the projected observations of *Victoria* and *Sappho* in 1889.

α Crucis has only been observed at one period, viz. in July, but it is hoped to be possible to obtain the July observations of 1889 without undue interference with the observations of *Victoria*. The observations of January 1889 will of course present no difficulty.

Observations which were begun on *τ Ceti*, and on second pairs for *Canopus* and *β Crucis*, had to be dropped.

Mr. Finlay has observed *α Scorpii* at one period of maximum displacement, and it will probably be possible to secure observations at two successive epochs (March and September 1889) without interference with the existing programme.

At the meeting of the Paris Astrophotographic Congress in 1887, preliminary arrangements were made between Dr. Elkin and H.M. Astronomer at the Cape for simultaneous observation of the minor planet *Iris* during its opposition in the months of October, November, and December 1888. The observations were to be made simultaneously at both observatories when the planet is in a plane passing through both observatories and the centre of the Earth. In other words, the angles between *Iris* and two stars (one above and one below the planet) were to be observed at both observatories when the planet was two hours west of the meridian at the Cape and four hours east of the meridian at New Haven. As the difference of longitude is 6^h,

the observations become practically simultaneous. Afterwards Dr. Bruns joined in the scheme with the Leipzig Heliometer. Full reports of the observations obtained at New Haven and Leipzig have not yet been received. At the Cape observations have been secured on forty-four mornings, as follows :—

Observer: Gill.	Observer: Finlay.
Oct. 12, 14, 21, 22, 24, 26, 29, 31	Oct. 13, 15, 21, 25, 27, 30
Nov. 2, 4, 5, 7, 9, 11, 13, 19, 21, 23, 29	Nov. 3, 6, 10, 12, 18, 20, 22, 24, 28, 30
Dec. 3, 5, 7, 9, 10	Dec. 2, 4, 6, 8

The observations of *Iris* at the Cape include about 1,000 bisections of the planet, all the observations having large parallax factors. Should the New Haven and Leipzig series include corresponding observations of even half that number, a very reliable value of the solar parallax will result.

An ephemeris of the planet and places of the comparison stars were distributed to the observatories at Greenwich, Dublin, Oxford, Melbourne, Cordoba, and Pulkowa, the directors of which cordially promised co-operation, and Dr. Auwers has secured the further co-operation of several German observatories. The discussion of these observations should insure an ephemeris of the planet sufficiently exact for the accurate reduction of the observations. Plans have been prepared for more complete and elaborate observation of *Victoria* and *Sappho* in June to December 1889. These plans involve the co-operation of the heliometer at Yale, Leipzig, Gottingen, Bamberg, and the Cape. Details of these plans will afterwards be communicated, and requests made for the co-operation of meridian observatories.

An account of the process of determining the errors of the scales of the heliometer has been communicated to the Society. The operation now progresses steadily at the rate of the complete inter-comparison of 10 divisions on each scale per week. But as each determination is controlled by an independent series derived from comparison with a different part of the other scale, the real progress is virtually only 10 divisions on one scale per week. There are in all 180 divisions on each scale—fully one-third of the whole work is now accomplished. The greatest discordance between any of the two independent determinations of the error of any single division is $0''{\cdot}030$. The complete operation involves over 45,000 bisections, but the detection of several accidental errors of division amounting to $0''{\cdot}2$, and many amounting to $0''{\cdot}1$, justify the necessity for this tedious and laborious undertaking.

The errors of the scale micrometer screw have been thoroughly determined.

During the past year the field work of the Geodetic Survey has been suspended, and Major Morris, R.E., has been engaged at the Observatory in the reduction of the results. The bars

used in the measurement of the base-lines at Natal and Port Elizabeth have been thoroughly compared with the Cape 10-foot standard bar A, the constants of which were determined at the International Bureau of Weights and Measures. For this purpose a *Comparateur*, devised by H.M. Astronomer, and constructed by Troughton & Simms, has been mounted in the S.E. room of the Observatory, and fitted with the necessary controlled hot and cold water supply. With this apparatus each of the five Cape base-bars have been compared with the standard bar, the latter being kept at a nearly constant temperature of 60°, whilst the former were compared with it at 50°, 60°, 70°, 80°, and 90° F., both at fixed temperatures and at gradually ascending and descending temperatures, in exact imitation of the increments encountered in the field. The probable error of a comparison at each temperature is about 1 *micron*.

With the new constants of the measuring-bars the lengths of the base-lines have been re-computed.

The Natal base was measured in three sections, each section being measured forwards and backwards. The results are:—

	I.	II.	III.
	Metres.	Metres.	Metres
Forwards .	1097·33764	1097·35875	1097·58438
Backwards .	·33897	·35920	·58322
F−B . .	− ·00133	− ·00045	− ·00116

The Port Elizabeth base was measured in eight sections, each section being measured "forwards" in the morning (that is, with increasing temperature), and "backwards" in the afternoon (that is, with falling temperature), with the following results:—

	I.	II.	III.	IV.
	Metres.	Metres.	Metres.	Metres.
Forwards .	213·36952	213·37356	213·37512	213·36440
Backwards .	·36924	·37359	·37439	·36423
F−B . .	+ ·00028	− ·00003	+ ·00073	+ ·00017

	V.	VI.	VII.	VIII.
Forwards .	213·36525	213·36625	213·36168	213·35685
Backwards .	·36571	·36604	·36232	·35674
F−B . .	− ·00046	+ ·00021	− ·00064	+ ·00011

Hence the probable errors of the measurement of the two bases, apart from the systematic error in the length of the bars, are:—

	Inch.
For the whole Natal base	± 0·024
Port Elizabeth base	± ·015

These results prove the efficiency of bent thermometers having their bulbs in mercury-wells to indicate truly the temperature of steel bars used in the field, provided that each bar is protected by a wooden casing with ample air-space, and these cases in turn protected from direct sunlight by portable huts such as were employed on the Natal and Port Elizabeth base-lines.

The two base-lines are connected by a nearly direct chain of 50 triangles, measuring 450 miles in length along the centre of the chain. Of these triangles 31 form parts of polygonal figures, and 19 are triangles forming a simple chain. In the first place, the angles of the whole of the polygonal figures were rendered rigidly consistent by the method of least squares, and the angles of the isolated triangles made equal to $180° + \epsilon$. The length of the Port Elizabeth base was then computed through the chain of 50 triangles from the Natal base, and found to differ 1·94 inch from its directly observed length. The small corrections applicable to the angles of the intervening triangles to equalise the computed with the observed lengths of the bases were then calculated by Clarke's method, the whole of the corrections being thrown upon the angles of the isolated triangles. When the angles of the 123 triangles (which constitute the whole work) were thus finally corrected and compared with the uncorrected angles as originally measured, the square root of the mean of the squares of the differences was found to be

$$\pm 0''{\cdot}56$$

so that the probable error of an observed angle throughout the principal triangulation is

$$\pm 0''{\cdot}38$$

In the prolongation, by triangulation, of the Port Elizabeth base to three times its measured length, the angles were observed at night. The station points were marked by small holes in discs micrometrically adjusted vertically over the dots marking the stations, and these holes, illuminated by bull's-eye lanterns, were observed as artificial stars. In the twenty-four triangles of this extension, which are not included in the above-mentioned 123 triangles, the *mean error* of a single angle has been similarly found to be $\pm\ 0''{\cdot}25$, or the probable error

$$\pm 0''{\cdot}17$$

The comparison of the astronomical latitudes, longitudes, and azimuths with the corresponding geodetic quantities (Clarke's elements) is now in progress, and will be completed early in 1889. A remarkable case of abnormal deviation of the plumb-line has been found at Port Elizabeth, and will be further investigated.

A reconnaissance survey for an arc of meridian connecting Port Elizabeth with Kimberley and Bechuanaland is in progress.

Major Morris leaves the Observatory in February to make further latitude determinations at stations surrounding Port Elizabeth, and will then re-measure a longitude chain of Baily's triangles connecting Maclear's work with the new triangles of the Geodetic Survey.

A new catalogue of 104 southern circumpolar stars, depending on the results of a very large number of double transits made in the years 1881 to 1888, has been prepared, and will soon be ready for press. The places of this new catalogue have been employed for computation of the azimuths of the transit-circle from 1885.

The Cape Catalogue of 1,714 stars, reduced to the equinox of 1885, depending on the results of the Cape meridian observations from 1879 to 1885, is now ready, except the application of final systematic corrections dependent on latitude flexure and refraction, for the full discussion of which the results of Greenwich and Leiden corresponding observations are awaited, as well as some further zenith telescope observations.

The preliminary results for the places of the fundamental stars of Schönfeld's *Durchmusterung* have been communicated in MS. to Dr. Auwers.

Miss Agnes M. Clerke, well known to astronomers by her "History of Astronomy in the Nineteenth Century," visited the Observatory during September and October, and besides carefully studying its practical working, made some original observations on the spectra of southern stars.

The Lords Commissioners of the Admiralty having sanctioned the acquisition of a suitable photographic telescope to enable the Observatory to take its share in the working programme of the Astrophotographic Congress of 1887, the telescope and dome have been ordered from Sir Howard Grubb, and the building of the Observatory has been commenced. The whole will probably be in working order before the end of 1889.

The meteorological observations made in the year 1887 at the Observatory, together with those taken in different parts of the colony, have been printed in the Report of the Cape Meteorological Commission.

Armagh Observatory.

After the completion of the Catalogue of Nebulæ the micrometrical observations of these objects were resumed with the 10-inch refractor. Differences of right ascension and declination with neighbouring stars which have been observed on the meridian are determined either with a filar micrometer, or by taking transits over a steel bar (without any illumination) inclined alternately at an angle of 45° and 135° to the parallel. This modification of Boguslawski's micrometer is very conve-

nient and the reductions are very simple; it was suggested by Professor Vogel, and is described in the *Astr. Nachr.*, No. 2835.

The occultations observed during the lunar eclipse of January 28 were published in the *Monthly Notices* for March 1888.

Cambridge Observatory.

This year has been exceptionally unfavourable for observations. Clock stars were observed on 117 nights, but of these only 64 nights were suitable for the observation of zone stars. The total number of observations for clock correction is 550. *Polaris* was observed above the Pole, directly 45 times, and by reflection seven times; below the Pole, directly 60 times, and by reflection 30 times; making in all 142 observations of *Polaris*, which involved 308 circle readings. The number of zone stars was necessarily limited, and consisted chiefly of very small stars which required a third observation, and stars in which discrepancies had been found in the formation of the Catalogue. The total number amounts to 860. Stars which had been compared with *Sappho* were observed 58 times; stars in the path of *Iris*, 108 times; and *Iris* itself, 16 times. Thus the entire number of meridian observations is 1,734. One hundred and twenty-four observations of each collimator, after adjustment horizontally, involving, of course, 248 circle readings, were made to obtain the coefficient of flexure.

The nadir point, level, and collimation were each determined 213 times.

The calculations of true right ascension and true north polar distance of all the stars are nearly completed up to December 1. The reduction to mean right ascension and mean north polar distance for January 1 of each year is completed to the end of 1883. The right ascensions are reduced to the epoch 1875 till the end of 1881, the north polar distances till the end of 1883.

The collection of zone observations for formation of Catalogue, from five hours R.A. to nine hours, is nearly completed till the end of 1878.

The observations of occultations of small stars by the Moon during the total eclipse of January 28 was an almost utter failure. The sky was clouded all the time, with occasional very imperfect breaks. In the few glimpses which were obtained of the Moon two emersions only were observed, and these not reliable, as it was by no means certain whether the appearances were owing to the clouds passing away or to the emergence of the star from behind the Moon. A list of 61 stars had been prepared, and arrangements made by which we hoped, with the aid of the square-bar micrometer, to secure nearly all of them. The two reappearances occurred at the very places where the observer was looking.

By request of Mr. Bryant the planet *Sappho* was observed

near the opposition with the Northumberland equatorial and square-bar micrometer. On four nights in April, 26 comparisons with selected fixed stars were obtained. The results were very consistent. The compared stars were subsequently observed with the meridian circle.

The observations for flexure of transit telescope are only partially reduced. The coefficient from 20 observations made on 20 separate days, June 20–July 13, is $-0''{\cdot}50$; precisely the same as that which was obtained from 200 observations made in 1885, May 29–July 17. That is, the arc from north horizon through zenith to south horizon is 180° 0′ 1″·00—according to the circle readings, instead of 180°. The correction of the circle reading for flexure, supposing it to vary as the sine of the zenith distance, will therefore be $-0''{\cdot}50 \sin z$, where z is the zenith distance, + when S, — when N.

The mean of 73 observations of *Polaris* above the Pole, made in 1887, reduced with assumed colatitude 37° 47′ 8″·4, and corrected for errors of division and flexure, give, for the correction of the Berlin N.P.D., $-0''{\cdot}41$, and 68 observations below the Pole give $+0''{\cdot}67$. These results give, for the correction of the Berlin N P.D., $+0''{\cdot}13$, and for the correction of the assumed colatitude, $+0''{\cdot}54$, making the colatitude 37° 47′ 8″·94. The observations of 1886 gave 8·96. Ten years—1878–1887—give 8·87.

Assuming the places in the *Berliner Jahrbuch* correct, 738 observations of clock stars made in 1887, not corrected for errors of division or flexure, give for the colatitude 37° 47′ 8″·883.

In the case of *Polaris* above and below the Pole, the errors of the divisions actually read off, compared with the reading of the nadir point, had been carefully determined. This has not been done for each individual clock star.

A few additional determinations of latitude have been obtained from direct and reflected observations of *Polaris*; but the entire series has not yet been discussed.

On September 12 Faye's Comet was sought for until daybreak with the Northumberland equatorial, in a perfectly clear sky, at and around the place given in the *Ast. Nach.*, No. 2856. No trace of it could be seen. This was the second morning that we had tried and failed. On the former occasion the sky was not so good; this morning it was perfect. The star DM + 17°1275, 6·3 mag., which was chosen as a comparison star and as our guide, has a very minute companion quite close s.f.

Several computers have drawn on us for places of small stars included in our zone, and we have been able satisfactorily to meet the demand.

Dr. Bernhard Schwarz, assistant in the Prague Observatory, has undertaken a recalculation of the orbit of Comet 1847 VI., sometimes called Miss Mitchell's Comet, and sometimes Dawes' Comet, for which Rümker found a hyperbolic orbit. He sent to ask for the data from which Professor Challis determined the places for October 11 and 12, published by him in the *Monthly*

Notices, vol. viii. p. 25. These have been found and recalculated by Mr. Graham, who has also found the two comparison stars of October 12 in the zone observations, each taken three times with the transit circle. All the details have been forwarded to Dr. Schwarz.

On April 5 a fresh determination of the intervals of the transit wires, from 101 observations of *Polaris* made in 1887, was completed. As this differed very slightly from the previous determination from 78 observations, and no accident has happened to the wires for several years, the two were combined, giving them the weights 9 and 7 respectively, and the necessary tables formed from the result.

A determination of the intervals has also been made from a large number of clock stars, but the results require re-examination.

On June 23 the object-glass of the transit telescope was taken out, and the lenses were separated and cleaned by a workman from the factory of Mr. Simms. A few spots had shown themselves between the lenses, but these were easily removed, and it was found that the lenses had suffered no damage. The line of collimation and nadir point were, of course, altered by the operation.

Dunsink Observatory.

The observations of the zenith distance of *Polaris* for determining the latitude of this Observatory, which were in progress at the date of last report, were brought to a close towards the end of January 1888. A discussion of the complete series gives for the value of this quantity $53^\circ\ 23'\ 13''{\cdot}2$, which differs from the value hitherto employed—that of Dr. Brünnow—by the one-fifth of a second. The latitude was also deduced from a number of observations of Auwers's stars, adopting their places as given in the *Berliner Jahrbuch*, and this result, combined with that derived from the *Polaris* series, gives $53^\circ\ 23'\ 13''{\cdot}1$. An account of the whole series of observations and the individual results is given in a paper read before the Royal Dublin Society in November, which will shortly be published.

During the spring and summer months systematic work with the meridian circle was discontinued, but early in September we received from Dr. Gill a list of the comparison stars which he proposed to use for heliometer observations of *Iris*. Work was at once commenced on this list, but, owing to the unpropitious skies which prevailed in October and November, its completion was very much delayed, and the last observation required was not obtained till the 10th of January, 1889. We have obtained from four to seven observations of each of the thirty stars on the list, and the results appear to be satisfactory. Their places have been referred, both in right ascension and declination, to a

few selected stars of the *Berliner Jahrbuch* which culminate immediately before and after the stars of Dr. Gill's list, and at about the same altitude.

These observations have been fully reduced up to December 26, so that it is hoped that the results will soon be ready for publication. At the same time we obtained 27 meridian observations of what was taken for the planet *Iris*. At first there was no difficulty found in its identification, but as the brightness diminished towards the end it is possible that one or two of the last few observations may prove to have been made on other stars, as it was sometimes difficult to decide which object in the telescope was the planet before it reached the wires.

The meridian circle has also been employed during the year for observing stars in connexion with the time service to Dublin.

On the night of January 28 the "South" equatorial was used, with the chronograph, for observing occultations of stars during the total eclipse of the Moon. Of these 17 disappearances and 18 reappearances were observed, of which a detailed account appeared at the time.

The "South" equatorial has also been employed as usual throughout the year in observing stars for parallax. Of these, 115 complete series of micrometric measures have been made.

Early in the year the Sixth Part of the "Dunsink Observations and Researches," containing the results of observations on 1,012 southern stars made with the meridian circle, was distributed as usual.

A 15-inch reflector, adapted for photographic work, has been presented to the Observatory by Mr. Isaac Roberts. It is about to be mounted in the small dome for the continuation of Parallax work by photography.

Glasgow Observatory.

The astronomical operations at the Glasgow Observatory during the past year have been mainly confined to the re-observation of a selected list of stars in the Glasgow Star Catalogue, the discordances between the places of which and those of Weisse's Bessel appeared to be greater than the ordinary errors of observation would warrant. It is expected that these observations will be brought to a close towards the end of the present year.

Kew Observatory.

The ordinary routine of meteorological and magnetical observations has been carried out during the year without alteration, and large numbers of scientific instruments have undergone examination as usual.

The sketches of Sun-spots, as seen projected on the photo-heliograph screen, have been made on 150 days, in order to continue Schwabe's enumeration.

Regular observations of solar and of sidereal transits have been taken, for the purpose of keeping correct local time at the Observatory, and the clocks and chronometers have been compared daily; but in addition to this, with a view of obtaining the time at the Observatory for pendulum work to a high degree of accuracy, and also for comparing daily the time as determined by the Observatory transit with that distributed by the Postmaster-General from St. Martin's-le-Grand, a telegraph line has been set up, placing the Observatory in direct electrical communication with the chief post office in Richmond.

A relay and chronograph have been purchased and placed in the circuit, and every morning, excepting Sundays and holidays, the 10 A.M. signal from the Royal Observatory, Greenwich, is recorded beside the beats of the Observatory standard clock (French) on the same tape. The signals have been observed daily by means of the galvanometer for the past two months, but the chronograph was only regularly set to work on October 31, delay having arisen on account of the necessity of protecting the apparatus from lightning.

The cost of the chronograph and attachments to the standard clock has been defrayed by a grant from the Royal Society.

Experiments were made during November and the early part of December to determine the time of vibration at pressures of 2 and 27 inches respectively of the Indian invariable pendulums Nos. 4, 11, and 1821, recently swung by American observers in different localities. After 14 sets of swings had been made with each pendulum, the apparatus was dismounted and wholly transferred to the Royal Observatory, Greenwich, where it is intended to repeat the swinging operations during the spring.

The vacuum correction of the two thermometers used on the dummy has also been determined. It was observed that a reduction of 27 inches in the barometric pressure lowered their zero points by 0°·25. Other observations were also made to find the relative degree of accordance during changes of temperature between the indications of the thermometers in the interior of the vacuum chamber and that attached to the Richard thermograph, placed in close proximity to its outer surface.

During the experiments the holding capacity of the chamber was thoroughly tested, and found to stand low pressures extremely well.

Old Mural Quadrant.—When in 1840 the astronomical instruments forming the equipment of George III.'s Observatory were removed to Armagh, it was found impracticable to take away the 8-foot mural quadrant by Sissons on account of its being too large to pass through the doors or windows of the room in which it was placed. Recently, advantage was taken of the removal of the roof of the east wing of the Observatory to

hoist it out and convey it to the Stores in the Office of Works at Kew, where it is now deposited. The Committee propose its ultimate consignment to the Loan Collection of Scientific Apparatus at South Kensington.

Liverpool Observatory, Bidston, Birkenhead.

The work has been carried on on the same lines as heretofore.

A large number of new chronometers have been tested during the past year in addition to those received from owners and masters of vessels frequenting the port of Liverpool. The test-certificates supplied with the instruments on their removal from the Observatory have been such as to enable the temperature corrections to be determined. The officers of the Pacific Steam Navigation Company have been furnished with the errors, and probable rates for each five degrees of Fahrenheit, from 45° to 95° inclusive, of their chronometers for the ensuing voyage.

Greenwich Mean Time has been communicated to the port daily, Sundays excepted, by the firing at 1 P.M. of the gun at the Morpeth Dock.

The meteorological work has proceeded as in previous years. No interruption has occurred in the records of the self-registering instruments.

Radcliffe Observatory, Oxford.

The following have been the subjects of observation during the year 1888:—

With the Transit Circle:—

(1) Observations of stars to the seventh magnitude inclusive between 115° north polar distance and the equator.

(2) Observations of the Moon, which are continued throughout the lunation and regularly compared with the right ascensions and north polar distances from Hansen's Tables. The mean error of Hansen's Tables for the period 1847 to 1863 amounted to $-1''\cdot30$, and there was no appearance of progressive increase; but with the mean solar times as now usually computed the mean error has progressively increased at the rate of $0''\cdot73$ per annum since 1864, and now amounts to $+17''\cdot7$.

(3) Observations of the Sun.

The following table gives the number of observations made during the year:—

Transits, 1,952.
Circle observations, 1,436.

These totals include:—

Observations of the Moon on 44 days.
„ „ Sun „ 34 „
118 determinations of Nadir Point.
5 vertical diameters of the Moon.
Comet (Barnard, September 2) on November 16, 20, 22, and 27.
The planet *Iris* on 18 days.
52 observations of 29 *Iris* comparison stars.
Observations of 2 *Sappho* comparison stars.

With the Barclay Equatorial:—

24 observations of 12 double stars.
10 „ Comet (Sawerthal).
4 „ „ (Barnard, September 2).
1 observation „ (Barnard, October 30).

Observations of occultations of stars during the total lunar eclipse, 1888, January 28.

Observations of these occultations were also made with the heliometer and the old seven-inch equatorial.

With the Heliometer:—

During the period October 10 to December 13 the heliometer was employed in the observation of *Iris* and its comparison stars, in accordance with a scheme of combined operations forwarded by Dr. Gill, but the weather was generally very unfavourable for the observations, which required a clear sky for several consecutive hours; and although observations were made on 17 nights, complete sets of observations with the instrument on both sides of the pier were obtained only on five nights.

The unusual prevalence of cloud during the year 1888 seriously interfered with the work of the observers, although special watches were put on to secure observations during the early mornings.

The volume for the year 1885 has been nearly passed through the press, and will soon be distributed.

The reductions for 1887 and the north polar distance results for 1888 have been completed; the right ascension reductions for 1888 are in a very forward state.

The meteorological observations have been carried on with the usual completeness, and include photographic registration of the changes of the barometer and dry and wet bulb thermometers.

University Observatory, Oxford.

The work at the Oxford University Observatory has proceeded steadily on its former lines. The press copy of the greater part of the stellar parallax work is completed, and it will be printed by the University and circulated without avoidable loss of time. The parallaxes of the following thirteen stars have either been completed or are in progress:—α, β, γ *Cassiopeiæ*, α *Cephei*, γ and ϵ *Cygni*, α and β *Andromedæ*, α *Arietis*, α *Persei*, β *Ursæ Minoris*, β *Leonis*, and α *Coronæ*. It has been already stated in a communication to the Society that, owing to the method of referring the star whose parallax is sought to four comparison stars, wherever possible, the *relativity* of the term 'stellar parallax' becomes more and more apparent.

In addition to the above, an inquiry was undertaken for the Photographic Committee of the Royal Society, in order to ascertain the comparative values of two mirrors of fifteen inches aperture, and of the focal lengths of 80 and 120 inches respectively. The result was an evidence of the practical superiority of the longer focus, and of the great advantages which may be expected from the application of mirrors to photographic researches. A report of this investigation was presented to the Royal Society, and published in their *Proceedings* of May 1888.

Much time has been necessarily expended on the erection of the photo-telescope for the international charting. The work was completed only at Christmas last. The driving mechanism may be regarded as successful, and the exposure of a photographic plate for several hours continuously can now be effected without intolerable stress to the observer. Hitherto no opportunity has occurred for an exposure beyond two hours. The present photographic object-glass is to be regarded as experimental only, and a greatly improved instrument is awaited, which in course of time Sir Howard Grubb will, no doubt, succeed in providing.

By the great courtesy of Admiral Mouchez and MM. Henry, a negative photographic plate of the *Pleiades* has been taken expressly for this Observatory, with a five minutes' exposure, on an average night. The perfection of the star images is very striking. The field also is measurable to the extent of a square plate $2^\circ \times 2^\circ$. Long experience of the difficulties inherent in the production of an available photographic object-glass has much enhanced the appreciation of MM. Henry's successful work herein.

So far as the light only is concerned, the photographic effects of the mirror and of the object-glass are practically equal.

Independently of astronomical work there are also important duties connected with University instruction, and in other similar directions. These have very properly consumed much time, but it may be doubted whether, after all, this variety of work is not of practical service to the Observatory, even in an astronomical point of view.

Temple Observatory, Rugby.

The usual instruction to members of the School has been continued, and the interest shown by boys has appeared to be on the increase during the past year.

Mr. Seabroke has continued the measurement of the motion of stars in the line of sight with the spectroscope on the reflector, and a new larger spectroscope has lately been brought into use.

Mr. Percy Smith left the Observatory at midsummer, and Mr. H. P. Highton has succeeded him, and has been practising with the micrometer with a view to continue the measurement of double stars.

Stonyhurst College Observatory.

In the course of the year a Rowland grating, $3\frac{1}{4}$ inches by $1\frac{5}{16}$ inch, has been mounted by Mr. Hilger, and now stands in the spectroscopic room adjoining the equatorial dome. As the instrument is intended principally for photographing the solar spectrum and spot spectra, the object-glasses of the collimator and viewing telescopes, which are three inches in diameter, are made of quartz. The plate-holder is arranged for making four exposures on the same plate, and it can be adjusted at any angle to the incident rays, so as to secure an exact focus for the extreme rays of the photo-spectrum. When the viewing telescope is used its position can be read by two micrometers on a 15-inch circle to within $0''{\cdot}25$. A stone pillar has been erected in front of the S.W. window of the spectroscopic room to support the heliostat and the $5\frac{1}{2}$-inch object-glass of Alvan Clark, which are to be used in connection with the grating spectroscope. The badness of the sky has so far interfered very much with preliminary experiments, but the photo-spectra already obtained show clearly what excellent results the instrument is capable of producing.

The 8-inch equatorial has been used during the day for solar work, and during the night for observing comets, occultations of stars, and the phenomena of *Jupiter's* satellites. Spectroscopic observations of the eclipsed Moon were made on January 28, and the 8-inch, $5\frac{1}{2}$-inch, and 4-inch equatorials were all employed in watching stars occulted by the Moon during the same eclipse. Barnard's Comets *e* and *f*, Sawerthal's Comet, and the minor planet *Sappho* were observed and some positions taken.

Large drawings of the Sun have been made on 223 days, and the solar surface was carefully examined on 18 additional days. These drawings have all been measured, and the spotted areas deduced. Complete measures of the chromosphere and prominences were secured on 84 days, together with partial results on three other occasions; and observations of the inclination or

apparent drift of the chromosphere flames were made with a wide tangential slit on 13 days.

Papers on the lunar eclipse, the solar surface, Barnard's Comet, *Jupiter's* satellites and lunar occultations have appeared in the *Monthly Notices*, and several communications have been sent to the *British Journal of Photography*.

The Rev. C. Colin, S.J., after spending twelve months at this Observatory, left in November for Antananarivo, to take the direction of the Government Observatory.

Mr. Common's Observatory, Ealing.

The 5-foot reflector was practically completed last September, and is now ready for work. On the few occasions that the weather has permitted, some trial photographs have been obtained that show a very satisfactory advance on those taken in 1883 with the 3-foot. It is intended to devote this telescope to the direct photography of the more important nebulæ and to spectroscopic work on such objects as can be best observed with such an aperture.

The 6-inch achromatic is in good order.

The transit instrument has been dismounted, and the room in which it stood used for a battery-room for two batteries of E.P.S. cells, available for lighting or power in the Observatory.

In the making of the 5-foot mirror much work was done of an experimental character in order to acquire the art of working glass. Many kinds of grinding and polishing substances, both for tools and for grinding or polishing the surface, were tried, as well as different lubricants and methods of testing. From the experience thus gained a definite plan of working and testing curved surfaces has been arrived at that is very certain, a mirror of 30 inches diameter having been since figured in a comparatively short time.

In addition to the machine made for the 5-foot mirror, on which mirrors of smaller size can be figured, another machine has been erected for grinding and polishing mirrors under 30 inches, both curved and plane, with means for figuring mirrors of very short focus. It is intended to prepare some mirrors of about 20 inches diameter, with a view of finding the shortest focus that will work, as such mirrors might be of great use on nebulæ, comets, and the corona during eclipse.

The Earl of Crawford's Observatory, Dun Echt.

In continuation of the work of preceding years, the transit-circle has been used by Dr. L. Becker chiefly in the observation of nebulæ, its large aperture recommending it for that purpose. On the whole, the weather was so unfavourable that the months

January to June afforded but 18 available nights, and September to December 20 nights: in all, 277 places of nebulæ were secured. On one-third of the observing nights it was clear for less than two hours. Fortunately, an improvement in the weather in the autumn permitted the observation of Comet 1888 *e* in the meridian on ten nights. The accurate co-ordinates of a number of comparison stars were also determined.

The study of the low-sun spectrum with the Rowland grating was continued on the Barmekin of Echt, by Dr. Becker, from June 16 to the end of September. Fifteen hours of actual observation, spread over 25 sunrises or sunsets, yielded 5,872 measures of lines, chiefly between *b* and F, which were checked by 6,518 positions of lines in the spectrum of the Sun at a considerable height above the horizon. These latter were obtained on nine days. The whole of the observations made in 1887 have been reduced to wave-lengths, and the remaining computations are in an advanced stage.

The 15-inch equatorial was used by Dr. Copeland for spectroscopic observations of nebulæ and bright stars. A considerable part of these was made with the Grubb stellar spectroscope, the smallness of the dome restricting the use of the large instrument by Cooke to objects of medium altitudes. Special attention was bestowed on the study of typical objects such as *o Ceti*, *β Pegasi*, *α Orionis*, *Arcturus*, and the great nebula in *Andromeda*. Including two nights in January 1889, the spectrum of Comet 1888 *e* was also observed on seven occasions. A few close double stars were measured in the autumn, but the season was very unfavourable as to definition, there having been only one really fine night (that of September 22) out of fifteen that were tried.

The comets of the year were usually observed micrometrically only when recent places were required for the computation or amendment of orbits. Comet Sawerthal was observed seven times; that of Brooks once; Comet *e* (Barnard) twice; and Comet *f* (Barnard) once. Most of these observations were made by Dr. Becker. Fifteen circulars, all relating to comets, were distributed in the past year, the larger part containing elements and ephemerides computed at Dun Echt.

The daily meteorological readings and the firing of the time-gun at Greenwich noon on Saturdays have been continued as in former years.

Much labour has been again devoted to the revisal of the manuscript and reading the proofs of the library catalogue, which is now nearly finished. It will fill about 500 quarto pages.

In view of the transference of the instruments and library to the Royal Observatory at Edinburgh, a revised and classified inventory has been drawn up. The instruments will probably remain in use at Dun Echt until some progress has been made with the new observatory buildings at Edinburgh.

Mr. E. Crossley's Observatory, Bermerside, Halifax.

As in past years, the phenomena of the satellites of *Jupiter* and *Saturn*, lunar occultations, and the measurement of double stars have formed the principal work of the Observatory. About thirty observations of the satellites of *Saturn* have been sent to Mr. Marth. The 3-foot reflector has occupied much of our time. The dome and the mechanism for moving it are in excellent order, and arrangements are being made for controlling the driving clock by Sir Howard Grubb's method, and a check telescope for photographic work has just been attached to the telescope.

Wolsingham Observatory (Rev. T. E. Espin's).

The search for stars with remarkable spectra has been continued during the year. In all, sixty-five such stars have been encountered in the sweeps, while fourteen of the variable stars have been observed with the spectroscope, in one of which, R *Cygni*, the F line has been found bright. Thirty stars given by various authorities as red have been also spectroscopically observed. One new variable star, R *Canum* ($\alpha = 13^h\ 42^m\ 43^s$ $\delta = +40°\ 15'{\cdot}9$; 1855) has been discovered. The variation is from 7·3 to below 13. In December the instrument was removed to the new observatory at Tow Law. The new observatory has a dome 20 feet in diameter, and is situated nearly 1,000 feet above the sea.

Mr. Huggins's Observatory.

The alterations and repairs of instruments reported in 1888 were continued. It should be specially mentioned that, since a new driving screw by Sir Howard Grubb has replaced the old one, the periodic irregularity of the motion, which was so unfavourable for spectrum work, has disappeared; now the action of the driving clock leaves but little to be desired.

These alterations and repairs have interrupted work but little in the last year. No possible opportunities of observing which have occurred have been lost. Though the weather has been exceptionally unsuitable for the purpose, photographs of the spectra of several nebulæ and of other objects have been obtained; but further photographs are wanted to complete the special investigation in hand before it is desirable to publish the conclusions to which they seem to lead.

Rousdon Observatory, Devon (Mr. Peek's).

Observations of long-period variable stars have been regularly made during the past year with the $6\frac{4}{10}$-inch equatorial telescope, 163 nights having been available for this purpose. The complete light curve has as far as possible been observed in each case. A sidereal clock by Sir Howard Grubb has been erected in the transit room.

The Earl of Rosse's Observatory, Birr Castle.

During the past year the work of the Observatory, Birr Castle, has been in the direction of the preparation of past observations for publication rather than in undertaking new investigations at the telescope. The total eclipse of the Moon on January 28, 1888, was, however, observed for radiant heat under exceptionally favourable circumstances, and the results, which were published shortly in *Nature*, February 2, 1888, and are now nearly ready for the press in their extended and fully reduced form, go to confirm those of October 4, 1884.

A detailed sketch of the Milky Way has been completed by Dr. Boeddicker, and only waits to be copied for the lithographer.

A long series of sketches of the planet Jupiter are nearly ready for issue with the *Transactions* of the Royal Dublin Society.

Some attempts at photography have been made, and it is hoped that in a short time it may be possible to adapt the instruments so as more nearly to meet the requirements of this new branch of work.

Meteorological observations continue to be made for the Government office as heretofore.

Sir Henry Thompson's Observatory, Hurstside, West Molesey, Surrey.

The dome and equatorial of this Observatory were constructed by Messrs. Cooke in 1887, but, owing to difficulties in obtaining a good flint lens, and to difficulties of mounting, the instrument was not ready for regular use until May 1888.

The objective of the equatorial is of 12 inches clear aperture, the focal length being 15 feet 3 inches. The dome, 30 feet diameter, has a framework of iron, and is covered with water-proof papier-mâché, the shutter being of Cooke's well-known pattern, allowing a wide opening near the zenith.

The Observatory being intended mainly for spectroscopic observations, Mr. Hilger was instructed to make a solar spectroscope with a 2-inch Rowland grating (14,438 lines to the inch).

The collimator and observing telescope of the spectroscope he constructed have achromatic objectives 2 inches diameter and 15 inches focal length, the whole being mounted in a convenient and effective manner, combining great rigidity with extreme lightness, 19 lbs. being the total weight. The micrometer of the spectroscope has powers of 50, 25, and 10, and is capable of measuring positions accurately to $\frac{1}{10000}$ of an inch.

Mr. Hilger also made a star spectroscope, which has been found very effective for observations of faint stars and of nebulæ.

Systematic observations of Sun spots and the widened lines in their spectra, and of the forms, sizes, positions, and frequencies of prominences, were commenced in May, and continued to the end of the year.

With the star spectroscope the bright lines in γ *Cassiopeiæ*, β *Lyræ*, P *Cygni*, R *Cygni*, and *Mira Ceti* were frequently examined and measured, and it is hoped that the results of these observations will be communicated to the Society at an early date. The spectra of the Great Nebulæ in *Orion* and *Andromeda*, and of the Ring Nebula in *Lyra*, were also examined: the results were recently communicated to the Society.

Comet Barnard (September 2, 1888) was observed on five occasions, spectroscopic observations being possible on three of these, viz. November 8, 13, and 27, 1888, the spectrum on each occasion showing three *excessively* faint bands and a rather bright continuous spectrum, the positions of the bands being 5640, 5169, 4742.

A room attached to the Observatory has been fitted as a spectroscopic laboratory, and another as a photographic dark-room.

Colonel Tomline's Observatory, Orwell Park.

The past year has not been favourable for the ordinary work of this Observatory. Only three months have had more than an average amount of clear weather, while the remainder fell generally much below it. Thus, although every opportunity was taken to observe Olbers' Comet from the beginning of the year up to March 21, when the watch was abandoned, only three observations could be secured. The results of the observations of the several comets of the year may be summarised in tabular form as follows:—

Comet.	No. of evenings on which observations were taken.	Limits of date within which observations were made.
Olbers' V. 1887	3	From Jan. 8 to Feb. 10
(concluding part of a series of 24 observations).		
Sawerthal I. 1888	24	From Apr. 3 to Aug. 10
Brooks III. 1888	13	„ Aug. 29 „ Oct. 8
Barnard *e* 1888	31	„ Sept. 11 „ Dec. 31
Barnard *f* 1888	7	„ Nov. 13 „ Dec. 30

Faye's Comet also was searched for on three occasions under favourable conditions as regards atmosphere, but it was not seen, and would appear to have been too faint for an aperture of 10 inches at this apparition.

The reductions of the above observations are all in an advanced state; those of the two former comets have been completed and published in the *Monthly Notices* of the Society, vol. xlix. No. 2, and the remainder will be communicated in like manner on the conclusion of the series, which, however, may possibly extend to some time yet.

Of miscellaneous work it may be mentioned that preparations for observing the occultations of small stars during the total eclipse of the Moon on January 28 were made, but were rendered futile by cloudy weather.

Hong Kong Observatory.

No report was drawn up last year owing to circumstances connected with a change of government in Hong Kong. His Excellency the present Governor has decided that purely astronomical observations are not to be subsidised here in future, but the magnetic observations are to be continued. The final reduction of all the double-star observations made since 1874 at Markree (and also a few in Hong Kong) by the present director of this Observatory was finished in the course of last year, and the final calculation of the orbit of the first comet of 1824, from observations made in Australia, will be done here.

The electric time-ball was dropped as usual at 1 P.M. The rate of the standard clock (with zinc and steel compensation) has been investigated, and the necessity of another standard clock (with mercurial compensation) has been recognised, and an order is being sent to a maker in London.

Sir W. Thomson's automatic tide-gauge has been working continuously, and two years' trace is now available. The electric light has been used for illuminating the wires in the transit instrument, and telephones and microphones for hearing the beat of the clocks at a distance, and for other purposes, and electric testing apparatus are being acquired.

The local meteorological observations and researches have been continued at the Observatory and at the Peak. Reports from about forty stations in China and in Corea have been utilised as far as funds were available. Extracts have also been made from log-books of vessels visiting the harbour. The typhoons from the beginning of 1884 till the end of 1887 have been exhaustively investigated, and data for investigating those of 1888 have been collected. Daily weather-reports and storm-warnings have been issued since 1884; but although gales caused by typhoons are frequent in summer and autumn, there

has been no opportunity for signalling a typhoon about to rage in the colony since September 1884.

The fourth annual volume of observations was published last spring, but it had unavoidably to be made smaller than in previous years. A fifth volume will probably be published early next year. The "Instructions for making Meteorological Observations in China" and "The Law of Storms in the Eastern Seas" have been republished by the Chinese Government under the auspices of the Imperial Maritime Customs.

Natal Observatory, Durban.

During the past year the work of the Observatory has been partially suspended for the same reasons which restricted its work during the previous year; but during this period the astronomer has found it possible to make considerable additions to the buildings by the construction of additional rooms and a new laboratory. The present year, 1889, finds the Observatory once more restored to its normal position, though the observing staff is still restricted to the astronomer and one assistant.

The principal work in progress at the Observatory is the comparison of the declinations deduced from observations made at observatories in the northern and southern hemispheres, by a comparison by Talcott's method of the zenith distances of northern stars with southern circumpolars both above and below the pole. During the year a number of observations have been obtained.

Considerable progress has also been made in the observations of pairs of equi-zenith-distance stars for the determination of the latitude of the Observatory, which forms the second fundamental point of the South African Geodetic Triangulation.

During the year the Greenwich Lunar Observations for the ten years 1878–1887 have been reduced and compared with the theoretical basis of Hansen's Lunar Tables in the same manner as those for the sixteen years 1862–1877 are reduced, compared, and discussed in the memoir on the "Corrections required by Hansen's *Tables de la Lune*"—Memoirs, 1885. The result shows that the application of the corrections deduced from the observations for the sixteen years 1862–1877 brings the tables into close agreement with the observations for the subsequent ten years, 1878–1887. The results of the discussion of these observations are being drafted for publication.

The observations of the lunar crater Murchison A, made by Mr. Campbell at the Arkley Observatory during the three years 1882–1884, have been reduced and compared with similar observations made at the Natal Observatory during the three years 1883–1885. The theoretical discussion of these observa-

tions with the similar ones made by Mr. Campbell at the Arkley Observatory during the years 1879–1881 is now in progress with the view of deducing values for the parallactic inequality, and the coefficients of the real libration in longitude and latitude, which shall be independent of the assumed value of the semi-diameter of the Moon.

Slow progress is being made with the researches on the lunar theory. The fundamental basis for the determination of the coefficients of the inequalities due to the disturbing action of the planet is complete, and only requires reduction to the ordinary form of expansion and to numbers. It is hoped that both time and health will be found during the coming year to effect much more work on these investigations than was found possible during the last two years, when nearly the entire routine work of the Observatory fell on the astronomer. The reduction of the tidal observations for Natal has been completed during the year.

Mr. Tebbutt's Observatory, Windsor, New South Wales.

The work of this Observatory rests upon one observer, and considering that he has been enabled to obtain occasional assistance only in the reductions, it has been rather heavy during the past year. The errors of the 3-inch transit instrument have been remarkably steady throughout, and the rate of the standard sidereal chronometer fairly good. Nine hundred and eleven star transits have been observed and reduced for time. The extra-meridian work accomplished with the $4\frac{1}{2}$ and 8-inch equatorials is as follows:—

Observations of the occultations of fifty-three stars by the Moon, comprising fifty-one disappearances at the dark and two at the bright limb, and three reappearances at the dark limb. Of the occulted stars forty have been identified and thirteen have had their places approximately determined.

Observations of the phenomena of *Jupiter's* satellites classified thus: Transit-ingress, I. 7, II. 5, III. 1. Transit-egress, I. 7, II. 6, III. 3. Occultation-disappearances, I. 7, II. 4. Occultation-reappearances, I. 2, II. 3, III. 1. Eclipse-disappearances, I. 5, II. 3, III. 5. Eclipse-reappearances, I. 7, II. 3, III. 6.

Observations of the occultations of *Venus* and *Saturn* by the Moon on March 9 and June 13 respectively.

Observations of both phases of the occultation of 47 *Libræ* by *Jupiter* on June 10.

230 filar-micrometer comparisons of *Jupiter* and *β' Scorpii*, on May 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25.

145 filar-micrometer comparisons of *Pallas* in high south declination on November 12, 13, 14, 15, 19, 20, 21, 26, December 1, 11, 14, 18, 19, 20, 21; and 10 square-bar comparisons on December 3.

Measures of 27 southern double-stars.

215 filar-micrometer comparisons of Comet *a* (Sawerthal), 1888, on the mornings of February 28, 29, March 3, 4, 5, 7, 8, 9, 10, 11, 12, 15, 16, 18, 19, 20, 22, 26, 29, 30, April 1, 2, 3.

63 square-bar comparisons of Encke's Comet on July 8, 10, 11, 15, 16, 18, 25, 26, 31, August 1.

157 square-bar comparisons of Barnard's Comet of September 2, 1888, on November 5, 10, 12, 13, 21, 22, 26, December 1, 2, 3, 4, 5, 23, 24, 25, 26. These observations have been carried into the current year. Faye's Comet was glimpsed with the 8-inch equatorial on December 3.

Determination of the magnitudes of μ *Argûs* and R *Carinæ*.

Sundry observations for determining instrumental constants.

In addition to the purely astronomical work, the usual 9^h A.M. meteorological observations have been made with great regularity.

Notes on some Points connected with the Progress of Astronomy during the Past Year.

Discovery of Minor Planets.

The following ten minor planets were discovered in the year 1888 :—

No.	Name.	Date of Discovery, 1888.	Discoverer.	Place of Discovery.
272	Antonia	Feb. 4	Charlois	Nice
273	Atropos	Mar. 8	Palisa	Vienna
274	Philagoria	April 3	,,	,,
275	Sapientia	15	,,	,,
276	Adelheid	17	,,	,,
277	Elvira	May 3	Charlois	Nice
278	Paulina	16	Palisa	Vienna
279	Thule	Oct. 25	,,	,,
280	Philia	29	,,	,,
281	Lucretia	31	,,	,,

Minor planet No. 269, discovered by Herr Palisa on Sept. 21, 1887, has been named *Justitia*.

The Comets of 1888.

In 1888, four comets have been discovered, and two comets of short period have been observed at their return to perihelion.

Comet I., 1888.—Discovered by Mr. Sawerthal of the Cape of Good Hope Observatory, on February 18, at which time the comet was visible to the naked eye. The nucleus shone as a star of the 7th magnitude, and was accompanied by a tail 2° in length. The northerly motion was more than a degree a day, so that the comet, notwithstanding its considerable southern declination when discovered, soon became visible in this hemisphere, and was very continuously observed up to the middle of July. It was visible to the naked eye in this country from April 7 to May 14. A distinguishing feature in the history of this comet has been the sudden outburst of brilliancy

which occurred about May 20, when the appearance of the comet indicated a sudden increase of light some five or six times greater than that possessed on the days immediately preceding. The spectrum of the comet has shown, in addition to the three characteristic cometary bands, a faint but fairly broad continuous spectrum. The path is fairly represented by a parabolic orbit, but elliptic elements have been computed by Dr. Berberich, which give a period of 2,370 years.

Comet II., 1888.—A return of Encke's Comet, which appears to have been first seen by Mr. Tebbutt, of Windsor, N.S.W., on July 8. Observations of position did not commence at the Cape of Good Hope till August 3, on which day the ephemeris, computed from preliminary elements supplied by Dr. Backlund, of Pulkova, showed an error of 8 secs. in R.A., and 1′·3 in declination. The geocentric motion of the comet at the time was rapid, so that this error does not point to any considerable alteration in the mean anomaly, and it was conjectured that owing to neglected perturbations the uncertainty of the ephemeris might amount to 3′. The circumstances of the return were very unfavourable to observation, and these difficulties were increased by the figure and general appearance. The last reported observation is August 9.

Comet III., 1888.—On August 7, Mr. Brooks, of Geneva, N.Y., detected a faint telescopic comet, at which date it had already passed its perihelion, and the brilliancy was diminishing. It was followed, however, at various observatories till the beginning of October, the observations being well represented by a parabolic orbit: the best is, perhaps, that of Dr. Krueger, in *Ast. Nach.*, No. 2855. The elements do not resemble any hitherto computed.

Comet IV., 1888.—A return of the comet of Faye. Dr. Perrotin, of the Nice Observatory, fortunately secured an observation of this exceedingly faint comet on August 9, but the faintness of the comet and the unfavourable position in the sky have prevented it being generally observed. Though the last published elements represented the place of the comet in 1880–81 within an error of only 1ˢ·5 in R.A., and 9″ in declination, yet Dr. Axel Möller found great difficulties in representing the observations at that apparition, and those difficulties not being yet wholly overcome, no accurate ephemeris was published from the Lund Observatory. In the absence of an accurate ephemeris, Dr. Kreutz published sweeping positions to assist in its discovery, and the deviation from these positions showed the necessity of an alteration in the assumed time of perihelion passage of 2·6 days. Though the theoretical brilliancy of the comet slightly increased after August, the comet does not appear to have been re-observed till December 3, when it was again seen at Nice.

At the Lick Observatory, U.S., on September 2, Mr. Barnard discovered a small telescopic comet, the perihelion passage of

which does not occur till the end of January 1889, so that the comet will appear in the catalogues of that year. It was described as circular, one minute in diameter, with a well-defined nucleus of the eleventh magnitude, or fainter. The distinguishing feature of the elements is the very considerable perihelion distance (1·82 R), and owing to this fact and the position of the orbit, the theoretical brilliancy will diminish so slowly that for a whole year after the discovery, the comet may be expected to shine as brightly as it did when first seen.

Comet V., 1888.—Another discovery of the same astronomer on October 30, and in general appearance resembling the last-mentioned comet. The perihelion passage was passed early in September, but observations will be possible for some time to come. There is, however, no indication of deviation from parabolic motion.

Among the contributions to cometary literature during the year may be mentioned a monograph by Dr. H. Kreutz of the great September Comet 1882 II., and which, in conjunction with investigations at present being carried on by Professor Weiss, will form a complete discussion of the cometary systems of 1843 I., 1880 I., and 1882 II., all marked by small perihelion distance. The present monograph is distinguished by a very able discussion of the remarkable changes in the appearance of the nucleus, which proved so troublesome to the observer. This change of form introduced such difficulties that Dr. Kreutz has declined to use the observations made after March 9, 1883, in the formation of the normal places.

Another valuable contribution is that of Dr. Haerdtl on the motion of Winnecke's comet, undertaken primarily with a view to detect if possible any increase in the mean motion, similar to that exhibited by Encke's comet, and which is not sensible in Faye's, possibly owing to its great perihelion distance. The discussion shows, however, that there is absolutely no increase of the mean motion in the case of Winnecke's comet, and so far the "resisting medium" theory obtains no support. Perhaps the more valuable part of the paper is the determination of the mass of *Jupiter* from the perturbations of the comet, for which constant Dr. Haerdtl obtains the following value, $\frac{1}{1047{\cdot}152 \pm 0{\cdot}0136}$.

W. E. P.

The Corona in 1887.

Most of the results obtained on the occasion of the total solar eclipse of August 19, 1887, have now been published, and it is therefore possible to formulate some conclusions as to the shape of the corona. For this purpose the most important materials available are three photographs taken at Yomeiji-yama, Echigo, Japan (longitude 139° E.), by Sugiyama, prints and copies on glass of

which have been received by the Society; and drawings from photographs taken in Russia, viz. at Petrovsk (longitude 39° E.), by Glasenapp, published in a Russian pamphlet; and at Jurjewetz (longitude 43° E.), by Bélopolsky, published in the *Annales de l'Observatoire de Moscou*. Of these drawings one in each set is distinctly better than the others, which are often faulty; in what follows, therefore, the remaining drawings will not be considered.

On careful comparison, these two are found to be in very satisfactory agreement, and we may therefore take them to correctly represent the corona as seen in Russia at $18^d\ 16^h\ 20^m$ G.M.T. The excellence of the Japanese photographs and their accordance *inter se* leave little doubt that they are an equally good picture of the corona as seen in Japan at $18^d\ 18^h\ 25^m$ G.M.T.

We have here, therefore, an opportunity of looking for changes in the corona in an interval of two hours. And from the evidence available there would appear to have been a well-marked change in one of the streamers. There are three streamers—roughly speaking, at the S., S.E., and E. of the Sun—separated by well-defined gaps. But in the Russian corona the southern gap is distinctly larger than the eastern, while in the Japanese the reverse is the case; so that the general mass of the south-eastern streamer appears to have moved southward in the interval. There are two reasons for considering that this change is real:—

(1) For the remainder of the corona, the accordance is remarkably good.

(2) The estimation of the position of the south-eastern streamer is made comparatively easy by the existence of the other two. It is difficult to believe that a mistake should be made in estimating which of two adjacent and similar gaps is the larger.

Dr. G. W. Hill's Determination of the Mass of Titan from the perturbations which it produces in the motion of Hyperion.

By means of his own observations of *Saturn's* outer satellite *Hyperion*, made during the oppositions from 1875 to 1883, combined with Mr. Lassell's observations of 1852, Professor Asaph Hall showed that the peri-Saturnium of *Hyperion's* orbit had an annual *retrograde* motion of nearly 20° (*Monthly Notices*, R.A.S., vol. xliv. p. 363).

At first sight this result appeared to be inconsistent with the law of gravitation, since in the case of a body moving in an eccentric orbit, and disturbed by another moving in a nearly circular one, the secular motion of the peri-centre given by the ordinary theory will always be *direct*.

The observations had shown, however, that the mean motion of *Hyperion* and that of *Titan*, which is the body which principally disturbs it, are nearly commensurable with each other, three times the period of *Hyperion* being nearly equal to four times the period of *Titan*; and in an able paper entitled "On the Motion of *Hyperion*: a New Case in Celestial Mechanics," published in 1884, Professor Newcomb showed that on account of this near approach to commensurability certain terms in the expression for the rate of motion of the peri-centre, which would otherwise be insensible, assume, on the contrary, a predominating influence. This important paper of Professor Newcomb has been already noticed in the Annual Report of the Council for 1885, but the following additional observations upon it may not be out of place here, especially as they may tend to make more intelligible the subsequent remarks upon Dr. Hill's treatment of the same problem.

If l and l' denote the mean longitudes of *Titan* and *Hyperion* at any time, n and n' their mean motions, and ϖ' the longitude of the peri-Saturnium of the latter body at the same time, then the observations of Professor Hall show that the mean motion of ϖ' is nearly equal to $4n'-3n$, and that if a year be taken as the unit of time the value of each of these quantities is nearly $-20°$. Now with the same unit of time the value of n is 8246° nearly, while that of n' is nearly 6180°, so that $4n'-3n$ is a very small quantity compared with n or n'; and Professor Newcomb's analysis shows that if both $4n'-3n$ and $\frac{d\varpi'}{dt}$ be very small quantities compared with n and n', and be also quantities nearly equal to each other, then the effect of the perturbing action of *Titan* upon *Hyperion* will be to make the mean value of $\frac{d\varpi'}{dt}$ to coincide with that of $4n'-3n$.

Hence if $V'=4l'-3l-\varpi'$, it follows that the angle V′ will oscillate about a mean value, which the analysis proves to be 180°.

From this it at once follows that *Hyperion* and *Titan* come into conjunction with each other only at or near the apo-Saturnium of the former satellite.

It should be remarked that an analogous proposition may be enunciated respecting the effects of the mutual action of the 1st and 2nd satellites of *Jupiter*, and also those of the mutual action of the 2nd and 3rd satellites of the same planet; only in both these cases the mean motions are nearly in the ratio of 2 to 1, instead of in that of 4 to 3.

A popular explanation of the way in which these perturbations are produced in the case of *Jupiter's* satellites is given in Section VI. of Sir George Airy's valuable work entitled "Gravitation," and in Art. (133) of that section the author remarks that "the same thing exactly would hold if the periodic

times were very nearly in the ratio of 2 : 3, or of 3 : 4, &c., but these suppositions do not apply to *Jupiter's* satellites." The ratio of 3 to 4 last named is the very one which obtains in the case of *Hyperion* and *Titan*.

Although there can be no doubt of the correctness of the general conclusions at which Professor Newcomb arrives in the memoir above referred to, it must be confessed that the numerical results which he obtains leave much to be desired. The method employed is the ordinary one in which the disturbing forces are developed in series proceeding according to powers of the ratio $\left(\frac{a}{a'}\right)$ of the semiaxes of the orbits of the disturbed and disturbing bodies. In the case of *Hyperion* and *Titan* this ratio is nearly 0·825, and consequently the convergence of the series employed is very slow, and a very large number of terms must be taken into account in order to obtain a good degree of approximation. A still more serious objection to the ordinary method of integrating the differential equations which proceeds by first neglecting the disturbing forces altogether, and then gradually takes into account the 1st, 2nd, and higher powers of the disturbing force, is that when the mean motions of the bodies are nearly commensurable, some of the divisors which occur in the integrations may be of the same order of smallness as the disturbing force itself, and thus terms which involve the first power of the disturbing force may after integration lead to others which are independent of the disturbing force. This would indicate that in such a case the ordinary form of solution would require to be changed, and that the arbitrary constants required to complete the solution would enter it in a different form in this special case from that in which they appear in the more general and usual case.

For example, if n and n' represent the mean motions of two satellites which disturb each other, n and n' in the general case are two independent arbitrary constants; but in the special case of *Hyperion* and *Titan*, n and n' are *not* independent of each other, but are connected by a relation of the form $4n' - 3n =$ a small constant depending on the mass of *Titan*, and the deficient arbitrary constant is replaced by another which determines the amount of the libration in the motion of the peri-Saturnium of *Hyperion*.

The same problem has been treated in a different way by M. Tisserand, and more fully by Professor Ormond Stone; but the numerical results which have been obtained by these mathematicians are unsatisfactory, owing to the slow convergence of the series employed to represent the co-ordinates of *Hyperion*, and the consequent necessity of taking into account a much greater number of terms than they have done.

In two papers, one of which appeared in June 1887, in Professor Ormond Stone's *Annals of Mathematics*, and the other in Dr. Gould's *Astronomical Journal* for July 12, 1888, Dr. G. W. Hill has attacked this difficult problem in an entirely

different way. He begins by discussing the particular case in which the inequalities of the longitudes and the radii vectores are all functions of the mean elongation of the two satellites from each other, so that when the satellites are in conjunction or opposition they are moving perpendicularly to their radii vectores. He assumes the mass of *Hyperion* to be so small that it may be altogether neglected, so that the motion of *Titan* may be considered to be purely elliptical, and in order to simplify the problem still more he assumes that the orbit is circular. By dividing any interval of time into a great number of small intervals the well-known method of mechanical quadratures enables us to find the co-ordinates of a body which starts from a given point with a given velocity and in a given direction, and is acted on by known forces, without its being necessary to integrate the equations of motion.

This process is attended with the advantage that no powers of the disturbing force are neglected.

Professor Hall's observations give us the average daily motion of *Hyperion* and its radius vector when in opposition to *Titan* compared with the radius of *Titan's* orbit, supposed circular. The mean daily motion of *Titan* is well known from Bessel's observations. Hence it is found that the interval between opposition and conjunction, or half the synodic period of the two satellites, is $31^{d}\cdot818$, and that the motion of the line of conjunction in this interval, which by what has been remarked before is equal to the motion of the line of apsides of *Hyperion* in the same time, is $-1^{\circ}\cdot638$.

In order to trace the path of *Hyperion* from opposition to conjunction by mechanical quadratures, two quantities, which are at first unknown, require to be determined, viz. (1) the velocity with which *Hyperion* starts from opposition, and (2) the mass of *Titan*. These are to be determined by the two conditions that (1) *Hyperion* must arrive at conjunction with *Titan* after the lapse of 31,818 days, and (2) that it must at that time be moving at right angles to its radius vector.

The values of these two unknowns must be at first assumed, and then corrected by making repeated trials until the required conditions are fulfilled.

An approximate value of the velocity of *Hyperion* when in opposition may be found from the elliptic elements of its orbit, which are approximately known from the observations; but the mass of *Titan* is at first supposed to be entirely unknown, and in order to find a first approximate value of this mass to be employed in the definitive calculations, Dr. Hill computed the motion of the line of apsides during the half synodic period from opposition to conjunction, neglecting all but the first power of the disturbing force, so that this motion is proportional to the assumed mass of *Titan*.

The first approximate value of the mass of *Titan* thus found is $\frac{1}{4466}$, the mass of *Saturn* being taken as unity.

The mass of *Titan* finally resulting from Dr. Hill's calculations is $\frac{1}{4714}$, and the osculating elements of *Hyperion* at opposition are :—

Mean daily motion = 60963″ ;

Mean distance from *Saturn* = 1·2088, the radius of *Titan's* circular orbit being unity ;

and the eccentricity of the orbit = 0·09947.

Dr. Hill gives a table which shows the difference between the mean and true longitude of *Hyperion*, and the value of the radius vector, corresponding to the argument days after, or days yet to elapse before, opposition with *Titan*. J. C. A.

M. Tisserand's "Traité de Mécanique Céleste."

Mons. F. Tisserand has very recently brought out an elegant volume, forming the first part of an extensive treatise on the *Mécanique Céleste*. This valuable work is founded on the lectures which the author has given at the Sorbonne since 1883, first as the deputy and afterwards as the successor of Mons. Puiseux.

The first volume is devoted to the general theory of perturbations, founded on the method of the variation of the arbitrary constants. The application of this method to the mechanics of the heavens is presented in two different forms, having reference to the labours of Jacobi and to those of Lagrange respectively. The theory of the method is one of great simplicity, though, perhaps, it does not always supply the most rapid means of actually calculating the perturbations. The author has thought it well to adopt the same formulæ and notation as those which have been employed by Le Verrier in developing the theories of the ancient planets, which have been published in the *Annales de l'Observatoire*, so that the present volume may be regarded as forming a very complete introduction to this work of Le Verrier.

In one chapter the author presents, in a succinct form, a theory of the functions of Bessel, and in another an investigation of Hansen's elegant formulæ for the development of certain functions of the co-ordinates in the case of elliptic motion.

A separate chapter is devoted to the subject of the discovery of *Neptune*.

In order to render his treatment of the theory of perturbations more complete, the author has added some interesting chapters treating respectively of Poisson's theorem respecting the invariability of the major axes of the planetary orbits, of Gauss's remarkable method of calculating the secular inequalities, and of Hansen's transformation of the differential equations, applied with so much success by him in determining the perturbations of the minor planets.

As might be expected, the greatest attention to elegance is shown throughout in the exhibition of the mathematical formulæ, and the attractiveness of the work is much enhanced by the beauty of its typographical execution. J. C. A.

Professor Oppolzer's Researches on the Lunar Theory.

In the 54th volume of the *Denkschriften* of the Imperial Academy of Sciences of Vienna there is published a very elaborate paper, entitled "Zum Entwurf einer Mondtheorie gehörenden Entwicklung der Differential-quotienten," by the late Professor von Oppolzer, and completed after his death by Dr. Robert Schram. A very full sketch of Professor Oppolzer's new method of treating the Lunar Theory is given by him in the 51st volume of the *Denkschriften*. In this method the Sun and Moon are referred to a system of moving rectangular axes, the axes of x and y at any time being in what may be called the plane of the Moon's mean orbit at that time, and that of z perpendicular to that plane. He then introduces what he calls "proportional co-ordinates" which are respectively equal to the real co-ordinates, each multiplied by a variable quantity $1+\gamma$.

Following the example of Hansen, Professor Oppolzer introduces a disturbed time ζ, and a corresponding disturbed mean anomaly, and the two proportional co-ordinates x_0, y_0 are treated as undisturbed co-ordinates which belong to the time ζ.

The determination of ζ, γ, and of the disturbed mean anomaly at any time is made to depend on the integration of certain differential equations involving functions of the co-ordinates which Professor Oppolzer denotes by I, II, III, IV′, and V′, and these integrations can only be performed by means of repeated approximations, first employing the undisturbed values of the functions which enter into them, and then repeating the process with more and more approximate values as they are successively determined.

In the paper now under notice, the first part of Professor Oppolzer's plan of operations is completed, viz. the development of the differential quotients $\frac{d\mathrm{I}}{dt}$, $\frac{d\mathrm{II}}{dt}$, &c., to the 8th order of small quantities, taking into account only the undisturbed values of the co-ordinates. The developments are purely analytical, and appear to have been carried out with the greatest care, all the calculations having been made independently by three computers.

The results are exhibited in tables which are very clearly arranged, so as to admit of very ready examination. J. C. A.

Professor Oppolzer's "Canon der Finsternisse."

A very important astronomical work is the *Canon der Finsternisse* of the late Professor Oppolzer, published as vol. lvii. of the *Denkschriften* of the Mathematical and Natural History Class of the Vienna Academy. It contains data for computing the circumstances of 8,000 solar eclipses between 1207 B.C. and A.D. 2161; and in the case of those which are total or annular, the first and last points of the Earth where the totality occurs, and the place where it occurs at noon, are given to the nearest degree of latitude and longitude. This information is rendered more available to the student of history by a series of 160 charts, which show approximately the position of the central lines for all such eclipses when they lie between the North Pole and 30° south. Further, for 5,000 lunar eclipses between nearly the same dates, there are data from which the time and magnitude of the greatest eclipse and the duration of both partial and total eclipses can be seen; and also, by the use of a table in the preface, one can easily determine whether any given eclipse has been or will be visible at any place whose latitude does not exceed $\pm 50°$. Of course the central line of solar eclipses is but roughly given on the charts, but the formulæ by which a more accurate determination of the course can be made are given fully and conveniently. Hitherto, for ancient eclipses we have only had the list by Pingré in *L'Art de vérifier les Dates*, a work which, meritorious as it was for its date, is so imperfect that it cannot be relied on. This "Canon" of Oppolzer's now entirely replaces it, and offers by its charts far greater convenience to the inquirer. It may not, then, be out of place to give some information as to the foundation of the computations.

Starting with Hansen's Tables of the Moon and Le Verrier's of the Sun, and comparing them with ancient solar eclipses, Professor Oppolzer found empirical corrections, which he ultimately reduced to the form of corrections to the time of conjunction, the longitude of the Moon, and her distance from the ascending node of her orbit. Applying these, he constructed Syzygy Tables (published by the Astronomische Gesellschaft in 1881), which give the means of readily computing the time of any full or new moon, and the elements for all solar eclipses.* In these tables, of course, all the equations with small coefficients are omitted. Tables for computing the lunar eclipses were published in vol. xlvii. of the Vienna *Denkschriften*; and, finally, these two sets of tables have been utilised in the volume which is the subject of this notice, and the result placed in a most convenient form before the student of eclipse lore.

* Professor Newcomb published Tables for Solar Eclipses in 1879, using his corrections to Hansen's Tables in forming them.

M. Lœwy's Method of Determining the Constant of Aberration.

The determination of the constant of aberration is one of the most complex problems in practical astronomy. The methods which have been adopted for its solution involve (if they are to be successful) the elimination of almost all the errors that can possibly affect an astronomical observation—an elimination which, it must be confessed, has hitherto only been partially achieved. Accidental errors of observation, accidental and systematic errors of instrumental constants, errors of the clock or of personal equation, as well as the uncertainty pertaining to the elements of reduction, especially to precession and nutation, of which an accurate knowledge is necessary in order to obtain the value of the constant of aberration to 0″·01 or 0″·02—all these sources of error have to be taken into account, and, if possible, their influence eliminated from the result. Nyrén has, in fact, put on record his opinion that none of the methods hitherto adopted have furnished a result free from systematic error. Under these circumstances it is a distinct advance to be able to determine the value of this fundamental constant from differential measures alone, thus avoiding the most serious of the difficulties which beset the investigator who proceeds along the old lines. This M. Lœwy enables us to do by proceeding according to the method which he explains, and the details of which he elaborates, in his collection of papers reprinted from the *Comptes Rendus de l'Académie*, tomes civ. et cv., entitled "Nouvelles Méthodes pour la Détermination de la Constante de l'Aberration." The principle of the new method is based on the observation of the distance of two stars by the aid of a prism-shaped double mirror, placed in front of the object-glass of an equatorial, by means of the two reflecting surfaces of which the images of two stars, situated in different parts of the sky, appear side by side in the field of the telescope, and their angular distance, in a known direction, can then be measured with a micrometer. To obtain the aberration it is, of course, necessary to observe the pairs of stars at successive epochs, and the results are compared in accordance with the theory of the subject which M. Lœwy has worked out. The first observation is made when the stars are at an equal altitude, above the horizon, and the second, after the prescribed interval, under the same circumstances. The difference of the measures gives a multiple value of the aberration free from instrumental errors and errors of refraction, and also free from errors arising from the use of erroneous values of precession, or nutation, or proper motions of the stars. In fact, with a double mirror of 45° angle, an interval of three months (thus avoiding observation during the daytime) is sufficient to give, for zodiacal stars, a variation in distance equal to twice the value of the constant of aberration,

whilst in the ordinary method the *maximum* difference is no more than this: aberration affecting the distance of two stars much more considerably than it does the co-ordinates of each.

M. Lœwy has worked out the details of his method both on the practical and theoretical side, and there is now nothing wanting to complete his work except an actual determination of the constant of aberration by the new method. This, from the completeness in detail of M. Lœwy's memoir, any one who has the requisite means and skill can do without much difficulty. We hope, however, that M. Lœwy himself will continue to give his attention to the subject (we understand that he is now engaged in the selection of suitable pairs of stars and other preliminary work), and will not rest from his labours until he has added to the great service which he has rendered to our science the achievement of a successful determination of this important astronomical constant. A. M. W. D.

Herr L. Struve's Determination of the Value of the Constant of Precession and of the Proper Motion of the Solar System.

An important paper has recently been published by Herr Ludwig Struve in the *Mémoires de l'Académie Impériale des Sciences de St.-Pétersbourg*, vii^e^ série, tome xxxv., No. 3, with the title, "Bestimmung der Constante der Präcession und der eigenen Bewegung des Sonnensystems." Herr Struve takes as the basis of his investigation the proper motions of more than 2,500 stars, deduced from the comparison of their positions for 1755, as given in Auwers' new reduction of Bradley's observations, with their positions for 1855, as given in the Pulkowa Catalogue of 3,542 stars for that epoch, and (for the fundamental stars) the two catalogues of Pulkowa fundamental stars for the epochs 1845 and 1865, from the mean of which the positions of the catalogue of 3,542 stars for 1855 have been deduced. In bringing up the star places from 1755 to 1855, O. Struve's constant of precession has been used. Feeling the force of Airy's objection to the method usually followed in investigating the direction of the solar motion, i.e. assuming the direction to be known, and determining a correction to it, Herr L. Struve has used Airy's formulæ in his researches, so that a correction to O. Struve's constant of precession and a determination of the R.A. and declination of the apex of the solar motion, as well as of the velocity of the latter, is found from the stellar proper motions, with no other assumption than that of the relative distances of stars of different magnitudes. These are taken in accordance with W. Struve's numbers, and this assumption is, of course, the weak point in this (as in other) investigations on the motion of the Solar System.

Proceeding in this way, Herr Struve finds the value of the

luni-solar precession for 1805 to be 50″·3514; Bessel's and O. Struve's values (both of them also deduced from Bradley's observations) being respectively 50″·3635 and 50″·3798. Correcting O. Struve's value for error of equinox in the *Fundamenta* and in the Dorpat observations, the difference between it and the present determination is reduced from 0″ 0284 to 0″·0147, which is no greater than might be expected, considering that the mean error of O. Struve's determination, which depends on 392 stars only, is ±0″·0112.

The co-ordinates of the point towards which the Solar System is moving are, from this discussion, A = 273°·3, D = +27°·3. From a consideration of the results which have been obtained by former investigators, Herr Struve concludes that the direction of the solar motion may now be considered known within not very wide limits, but that the variation in this direction, depending on the time, is still unknown. Combining the most trustworthy results for the co-ordinates of this point, we have A = 266°·7 and D = +31°·0. With regard to the velocity of motion of the Solar System some very discordant results have been obtained. The present discussion gives for the motion of the Solar System in 100 years, in a direction at right angles to the line of sight, as seen from a star of the sixth magnitude, the quantity 4″·36. O. Struve and Dunkin found for the same quantity the values 4″·31 and 5″·22 respectively. The mean of the three determinations is, therefore, 4″·63. Other astronomers, however, who have attacked this question in different ways have found very different results, and too much reliance must not be placed on the value given above, which is deduced from accordant, but not altogether independent, separate determinations.

Herr Struve's results depend on a larger number of stars than have hitherto been used by any investigator in researches on these subjects, and astronomers will appreciate the laborious zeal with which he has discussed the proper motions of such a large number of stars, and will hail with satisfaction the appearance of another determination of a fundamental astronomical constant from the Pulkowa Observatory, which has already done so much for the advancement of practical astronomy. A. M. W. D.

Mr. Lockyer's Meteoric Hypothesis.

During the past year Mr. Lockyer has continued his researches on the spectra of meteorites in connection with the spectra of the heavenly bodies. The outcome of some of his inquiries formed the subject of the Bakerian Lecture at the Royal Society last April, under the title of "Suggestions on the Classification of the Heavenly Bodies." His wide induction as to the meteoritic constitution of the universe, to which reference was made in last year's report, was there extended, and various

tests as to the probable truth of the hypothesis applied. The general basis of the hypothesis is that all the bodies in the universe are or have been swarms of meteorites, the present differences between them depending upon differences of temperature (the heat being brought about by collisions due to gravity) and the differences in the distances apart of the constituent meteorites.

One of the tests applied to the general hypothesis was that of the forms of nebulæ, and Mr. Lockyer has demonstrated that globular and spherical nebulæ, which have never been satisfactorily explained before, may be well explained by regarding them as collision shells in a swarm in which the meteorites revolve in orbits round a common centre of gravity. Further, cometic nebulæ can also be explained on the supposition that a very condensed swarm is moving at a high velocity through a sheet of meteorites at rest, or the swarm may be at rest and be surrounded by a moving sheet; the disturbance set up would thus gradually spread out like a fan behind the nucleus.

The main part of the paper, however, dealt with the classification of stars. Mr. Lockyer pointed out that, although nebulæ and comets have hitherto been regarded as things quite distinct from stars, this distinction no longer holds. Further, it is shown that all previous classifications of stars, which are based on the assumption that all stars are in a state of cooling, must give way if there be a line of increasing as well as a line of decreasing temperature; that is, if some stars are getting hotter while others are getting cooler. It having been demonstrated that the old Class III*a* stars are meteor-swarms which will ultimately develop into the *α Lyræ* type by the complete vaporisation of the constituent meteorites, and that the Class III*b* stars have run through all the other stages, it is clear that the III*a* stars and the III*b* stars cannot possibly represent either successive stages or different types of the development of any stage, as Vogel's classification supposes.

The new classification suggested is based on the existence of bodies which are increasing in temperature as well as of bodies which are decreasing in temperature.

The following is a statement of the new groupings:—

GROUP I. Radiation lines and flutings predominant. This group includes nebulæ, comets near aphelion, and the so-called "stars" with bright-line spectra.

GROUP II. Mixed carbon fluting radiation and metallic fluting absorption predominant. This group corresponds to the old Class III*a*, and includes some comets near perihelion.

GROUP III. Line absorption predominant, with increasing temperature. The more advanced species will be marked by greater simplicity of spectrum.

This group comprises *some* of the members of the old Class II*a*.

Group IV. Simplest line absorption (hydrogen) predominant. This group corresponds to Class I., and includes only the very hottest stars.

Group V. Line absorption predominant, with decreasing temperature. Those stars of Class II*a* which do not fall in Group III. will fall in this group.

Group VI. Carbon absorption predominant. This group corresponds to the old Class III*b*, of which 152 Schj. is the type.

Group VII. Dark or nearly dark planetary bodies.

It will be seen that in this new classification there are several fundamental departures from previous ones, chiefly as regards the separation of the III*a* and the III*b* stars, and the separation of the bright-line stars from stars of the *α Lyræ* type. It also includes nebulæ, and comets in their various stages, which the older classifications do not take into account at all.

Another very important difference lies in the division of the old Class II*a* stars into two groups, one representing increasing and the other decreasing temperatures. On the ascending side of the temperature curve the varying volatilities of meteoritic constituents brought out by successively higher temperatures are in question, whilst on the descending side of the curve the spectra will depend upon successive chemical combinations rendered possible by a gradual reduction of temperature in a gaseous mass.

The spectroscopic observations of the II*a* stars have hitherto been made on the supposition that all of them were cooling bodies, so that no effort has been made to establish the necessary criteria.

Mr. Lockyer has since succeeded in determining some of the spectroscopic criteria which will enable observers to assign any particular Class II*a* star to either Group III. or Group V., as the case may be, of his new classification.

As a test of the truth of the hypothesis, Mr. Lockyer shows how it bears the strain put upon it when it is used to indicate how the groups should be still further divided, and what specific differences may be expected. Thus, the first species of Group I. will include the least condensed swarms, and succeeding species will include the more condensed ones. The last species of all will consist of the hottest of the "stars" with bright lines, like *γ Cassiopeiæ*. In passing through this series, the spectroscopic differences observed between the different species are just what would be expected on the supposition that meteorites at gradually increasing temperatures are in question, and the general hypothesis is thus greatly strengthened.

It is also shown that if the next group (Group II.) be dis-

cussed in a similar manner the same conclusion is arrived at. The actual spectroscopic differences observed are exactly what they would be in a condensing swarm of meteorites with a gradually increasing temperature. The 297 stars of this group which have been observed by Dunér have been divided by Mr. Lockyer into fifteen well-defined species, the first beginning where the last of the preceding group leaves off.

The subject of variability, as far as it is associated with the stars which Mr. Lockyer considers to be uncondensed meteor-swarms, was also discussed at some length in the Bakerian Lecture. Mr. Lockyer's explanation of variability is closely allied to that of Newton, who ascribed the increase of brightness to the appulse of comets.

According to Mr. Lockyer, however, the variability in this class is produced in the simplest case by the revolution of a small meteor-swarm round a central one, the maximum occurring at periastrion. The greater the eccentricity of the orbit of the revolving swarm, the greater will be the difference between the luminosity at maximum and that at minimum. Variables of this group are, therefore, to be regarded as incipient double stars, the invisibility of the companion being due to its nearness to the primary, or to its faintness. The question of variability affords several tests of the general hypothesis. According to the hypothesis, stars of Group II. ought to be more subject to variability than the other groups, and, as is well known, this is the case. Variability ought also to be most common in the swarms with a mean condensation, for the reason that at first the meteorites are too sparse for many collisions to occur, and that finally the outliers of the central swarm are drawn within the orbit of the revolving swarm, so that there are very few additional collisions at periastrion. A discussion of the recorded observations has shown that this is the case, the greatest number of variables occurring in those swarms where spectroscopic observations indicate mean spacing. In cases where there is more than one maximum it is suggested that more than one revolving companion is concerned. This general view of variability, however, does not exclude other causes, such as eclipses by dark companions.

In a later paper, read at the Royal Society on January 10, 1889, Mr. Lockyer discussed the spectra of comets and the aurora, and the origin of binary stars, with the special object of testing the general hypothesis. The first part of the paper dealt with the spectra of comets. It being generally accepted that comets are meteor-swarms in the solar system which get brighter, and therefore hotter, as they approach the sun, if the hypothesis be true, the changes in their spectra ought to resemble those which take place in gradually condensing swarms outside the solar system. A detailed discussion of all the available spectroscopic observations of comets shows that this demand is satisfied by the facts. An important outcome of Mr. Lockyer's investi-

gations of cometary spectra is the unravelling of the spectroscopic phenomena produced by the integration of various simple spectra. The cause of the variation in the form of the citron band in cometary spectra, for example, has always been a difficult question, but Mr. Lockyer shows that such variations as are observed are not only explained but demanded by his hypothesis. Allowing for the differences in the conditions of observation, it is conclusively shown that the sequence of spectra is the same in comets as in condensing nebulæ. In both cases, when the number of collisions is just sufficient to render the swarms visible, *i.e.* in comets at aphelion and planetary nebulæ, the spectra are identical, consisting simply of magnesium radiation (λ 500). With the first increase of temperature continuous spectrum is added in both cases. As the nebulous swarm condenses, an apparent star, with a spectrum consisting of bright flutings and lines, is the result, and this is also the case in cometary swarms. Still further condensation of the nebulous swarm results in a body of Group II. giving mixed carbon radiation and metallic fluting absorption; and this, also, is a well-marked stage in the development of cometary spectra. Further condensation in both cases results in line absorption. Schiaparelli's view, therefore, that comets consist of nebulous materials drawn into the solar system by solar attraction, is now abundantly demonstrated by the spectroscopic study of nebulæ and comets. The discussion of cometary spectra, therefore, strengthens the general hypothesis, which would have been worthless had the cometary spectra been otherwise.

In the second part of this paper Mr. Lockyer proceeds to test his hypothesis by a discussion of the spectrum of the aurora. He points out that if in the aurora the solid particles of the meteorites, which are constantly entering our atmosphere, are acted upon by the electric current the spectroscopic phenomena observed ought to be similar to those observed in our laboratories when meteoric dust is subjected to electric discharges in vacuum tubes. It has never been possible to reconcile the aurora spectrum with any known spectrum of air, and some investigators have attempted to get over this difficulty by assuming that the aurora is produced under conditions of temperature and pressure which we are unable to imitate in our laboratories. A comparison of the aurora spectrum with the spectra of uncondensed meteor-swarms (γ *Cassiopeiæ*, &c.), however, indicates a very intimate relation between the two apparently different classes of phenomena.

The meteoric dust theory of the aurora, as first enunciated by Olmsted during the display of 1833, has practically been rejected, because the lines of iron were not seen in the aurora spectrum. But Mr. Lockyer's experiments show that the iron lines ought not to be seen except in auroræ of exceptionally high temperature.

The principal line in the aurora spectrum is shown to be in

all probability the remnant of the manganese fluting at λ 558. This fluting is found in every meteorite which has been spectroscopically examined at a low temperature, and, moreover, it is seen long before the iron with which it is associated in meteorites.

Even the small trace of manganese in the purest electrolytic iron is sufficient to render this fluting visible before the iron lines. The secondary lines seen in the aurora spectrum also appear to be due to constituents of meteorites which are most volatile at the lowest temperatures. The reason why the lowest temperature spectrum in nebulæ should be that of magnesium, while in the aurora it is manganese, Mr. Lockyer explains that in nebulæ heat due to collisions is in question, while in the aurora electrical conductivity as well as heat is in question. Magnesium, being mainly in combination with silica in the meteorites, would not be so likely to appear in electrical excitations as would the volatile metallic constituents.

There is, therefore, apparently strong evidence that the spectrum of the aurora is due to the presence of meteoric dust in the upper parts of the air, and the investigations strengthen the general meteoric hypothesis.

In the third part of the paper the hypothesis is further tested by a discussion of binary stars.

If the apparently single variables of the *Mira* type are really double nebulæ, as the hypothesis supposes, visible physical doubles are probably only further advanced stages, and by an investigation of the spectra of the components, or of their colours where spectra are not available, it ought to be possible to determine the stage of condensation of such double nebulæ. The main idea is that the component with the smallest mass will run through its changes at a greater rate than the other component.

According to the relative stages of development of the two components (or indirectly to their relative masses), Mr. Lockyer divides the known physical doubles into five classes.

There are really only three cases in which the components do not appear to have condensed from double nebulæ, and here the companions are probably additions of a cometary nature. The general view that the regular variables of Group II. are really double nebulæ is therefore strengthened by this investigation. The irregular variables of the group are regarded by Mr. Lockyer as multiple nebulæ, which will ultimately form multiple stars.

Throughout both papers, references are made to special laboratory researches on which most of the conclusions are based. In the case of the aurora, the meteoric theory is greatly strengthened by observations of an air vacuum-tube five feet in length, and by observations of the spectra of some of the manganese nodules dredged from the bed of the Atlantic by the "Challenger."

Professor G. H. Darwin on the Meteoric Theory of Cosmogony.

The publication of Mr. Lockyer's paper has led Professor George Darwin to make a suggestion for the reconciliation of two apparently divergent theories of the origin of planetary systems.*

He points out that the nebular hypothesis depends essentially on the idea that the primitive nebula is a rotating mass of fluid, which at successive epochs becomes unstable from excess of rotation, and sheds a ring from the equatorial region.

But, notwithstanding the high probability that some theory of the kind is true, the acceptance of the nebular hypothesis presents great difficulties. Amongst others it has been from time to time urged by various astronomers and physicists that the most probable origin of the planets was through a gradual accretion of meteoric matter, and the researches of Mr. Lockyer now afford actual evidence of the abundance of meteorites in space.

But the very essence of the nebular hypothesis is the conception of fluid pressure, since without it the idea of a figure of equilibrium becomes inapplicable. Now, at first sight, the meteoric condition of matter seems absolutely inconsistent with a fluid pressure exercised by one part of the system on another. We thus seem driven either to the absolute rejection of the nebular hypothesis, or to deny that the meteoric condition was the immediate antecedent of the Sun and planets.

Professor Darwin, however, maintains that by a certain interpretation of the meteoric theory we may obtain a reconciliation of these two orders of ideas, and may hold that the origin of stellar and planetary systems is meteoric, whilst retaining the conception of fluid pressure.

According to the kinetic theory of gases fluid pressure is the average result of the impacts of molecules. If we imagine the molecules magnified until of the size of meteorites, their impacts will still, on a coarser scale, give a quasi-fluid pressure. He suggests then that the fluid pressure essential to the nebular hypothesis is in fact the resultant of countless impacts of meteorites.

The problems of hydrodynamics could hardly be attacked with success if we were forced to start from the beginning and to consider the cannonade of molecules. But when once satisfied that the kinetic theory will give us a gas which, in a space containing some millions of molecules, obeys all the laws of an ideal non-molecular gas filling all space we may put the molecules out of sight and treat the gas as a plenum.

Laplace's hypothesis implies a plenum, subject to the laws of fluids, and Professor Darwin maintains that this plenum is merely the idealisation of the impacts of meteorites.

* *Phil. Trans. Roy. Soc.* vol. 180 (1889), A, pp. 1–69.

If a kinetic theory is to be applicable the colliding bodies must be highly elastic, and it is urged in the paper that when two meteorites meet with planetary velocity the sudden volatilisation of solid matter at their point of contact will act like an explosive, and that virtual elasticity will be thus imparted to meteorites in collision. The recondensation of gases generated in collision and the fusion of particles together will serve to counteract the fractures which must often occur.

But, if it be admitted that a kinetic theory of meteorites is thus far possible, yet the acceptance of the theory must depend on numerical values which can only be derived from the consideration of an actual system.

Professor Darwin accordingly imagines the sun to be broken up into a number of meteorites, which are distributed in a swarm extending beyond the orbit of the planet *Neptune*. These meteorites are supposed to be in motion, and to derive their velocities from their fall together from a condition of wide dispersion. If the kinetic theory be provisionally accepted, it is possible to calculate the arrangement of meteorites in space, for the density of distribution follows the same law as the density in a gaseous star in equilibrium under its own gravitation. This is a problem which has been considered by M. August Ritter in a series of papers contributed to the *Annalen der Physik* between the years 1878 and 1883, and many of his results are reinvestigated in this paper by different methods. When the mean velocity of the meteorites and their distribution have been found, it remains to compute the frequency of their collisions, and then to apply a criterion which shall determine whether the mechanical properties of the medium can be sufficiently like those of a fluid to allow of the truth of the nebular hypothesis.

These and other cognate problems are treated in the paper, and the principal conclusions arrived at may be summed up as follows:—

When two meteorites are in collision, they are virtually highly elastic, although ordinary elasticity must be nearly inoperative.

A swarm of meteorites is analogous with a gas, and the laws governing gases may be applied to the discussion of its mechanical properties. This is true of the swarm, from which the Sun was formed, when it extended beyond the orbit of the planet *Neptune*.

When the swarm was very widely dispersed the arrangement of density and of velocity of agitation of the meteorites was that of a gas under its own gravitation.

The actual mean velocity of the meteorites is determinable in a swarm of given mass, when expanded to a given extent.

The total energy of agitation in a spherical swarm is half the potential energy lost in the concentration from a condition of infinite dispersion.

The half of the potential energy lost, which does not re-

appear as kinetic energy of agitation, is expended in volatilising solid matter, and heating the gases produced on the impact of meteorites. The heat so generated is gradually lost by radiation.

The amount of heat generated per unit time and volume varies as the square of the quasi-hydrostatic pressure, and inversely as the mean velocity of agitation. The temperature of the gases volatilised probably varies by some law of the same nature.

The path of a meteorite is approximately straight, except when abruptly deflected by a collision with another. This ceases to be true at the outskirts of the swarm, where the collisions have become rare. The meteorites here describe orbits under gravity which are approximately elliptic, parabolic, and hyperbolic.

In this fringe to the swarm the distribution of density ceases to be that of a gas under gravity; and as we recede from the centre the density at first decreases more rapidly, and afterwards less rapidly than if the medium were a gas.

Throughout all the stages of its history there is a sort of evaporation by which the swarm very slowly loses in mass, but this loss is more or less counterbalanced by condensation. In the early stages the gain by condensation outbalances the loss by evaporation, they then equilibrate, and finally the evaporation may be greater than condensation.

Throughout the swarm the meteorites are to some extent sorted according to size; as we recede from the centre the number of small ones preponderates more and more, and thus the mean mass continually diminishes with increasing distance. The loss by evaporation falls principally on the small meteorites.

A meteor swarm is subject to gaseous viscosity, which is greater the more widely diffused is the swarm. In consequence of this a widely extended swarm, if in rotation, will revolve like a rigid body without relative motion (other than agitation) of its parts.

Later in the history the viscosity will probably not suffice to secure uniformity of rotation, and the central portion will revolve more rapidly than the outside.

The kinetic theory of meteorites may be held to present a fair approximation to the truth in the earlier stages of the evolution of the system. But later the majority of the meteors must have been absorbed by the central Sun and its attendant planets, and amongst the meteors which remain free the relative motion of agitation must have been largely diminished. These free meteorites—the dust and refuse of the system—probably move in clouds, but with so little remaining motion of agitation that (except perhaps near the perihelion of very eccentric orbits) it would scarcely be permissible to treat the cloud as in any respect possessing the mechanical properties of a gas.

Harvard Zone Observations made with the Transit Wedge Photometer.

Professor Pickering has recently published in vol. xiii., part 2, of the Annals of Harvard College Observatory an important catalogue of 4,143 stars of the 8th to the 14th magnitude in the zone $+0^\circ\ 50'$ to $1^\circ\ 0'$, the magnitudes being measured by a novel application of Professor Pritchard's wedge photometer. The transit wedge photometer consists of an ordinary wedge of tinted glass cemented to a glass plate carrying an opaque bar or heavy line parallel to the thinner end of the tinted wedge. This plate is placed in the focal plane of the telescope, and the bar is made coincident with an hour circle. The interval between the transit of a star across the bar and its disappearance in the wedge is the observed quantity from which the brightness of the star is to be deduced.

The particular wedge employed by Professor Pickering had the form of a square, the side of which was about 2·3 cm. in length, corresponding to $11'{\cdot}6$ in the field of the telescope. The bar over which the transits were observed was of tinfoil about 0·3 cm. from the edge of the wedge; three shorter bars were placed at right angles to the first, at intervals corresponding to $5'$ in the field of the telescope.

Upon the assumption that the light which traverses an absorbing medium is reduced in a constant ratio by its passage through a given quantity of the medium, the light of a star passing behind the wedge would vary in such a manner that equal intervals of time would correspond to equal differences of magnitude, if magnitude be expressed in the usual logarithmic scale. Upon this system the observations have been reduced. A careful discussion of the instrumental errors is given, and a determination of the constants. The method of observation was to record upon the chronograph the times at which the stars disappeared behind the bar parallel to the thin edge of the wedge, and their subsequent disappearances in the wedge itself, the observer calling out at the time an estimation of the declination of the stars in minutes and tenths, reckoning from the southern of the three bars forming the declination scale. By these means it was found possible to measure the brightness and approximate position of stars so faint as the 14th magnitude.

This work has been carried out in the complete and exhaustive manner that characterises so many of the researches at this Observatory, and the resulting catalogue forms a very interesting contribution to Photometric Astronomy.

Christiania Zones.

The Director of the Observatory of Christiania, Professor C. Fearnley, and Herr H. Geelmuyden, have published the zones between +64° 50′ and +70° 10′ undertaken for the Astronomische Gesellschaft. The first zone was observed February 17, 1870, the 310th and last, May 13, 1887. The observed places are reduced to 1875·0 in accordance with the general plan. This makes the fourth contribution to the series.

The Leyden Zones were published in 1875; the Helsingfors in 1883 and 1885; and the Kasan in 1886. The zones undertaken at Albany, N.Y., have long been concluded, but unfortunately no funds can be obtained for their publication—a very remarkable circumstance in the United States, where so much is given for the advancement of Astronomy.

Zone Catalogue of 4,050 *Stars of the Cincinnati Observatory.*

This publication contains the results reduced to 1885·0 of the zones observed with the 3-inch transit instrument during the years 1885, 1886, and 1887. The zone of the heavens included lies between 18° 50′ and 22° 20′ of south declination. Within these limits, it is stated, most of the stars down to the $8\frac{1}{2}$ magnitude have been observed. The accuracy of the positions is not so great as the director could have wished; but for the purpose for which it is intended the catalogue is most valuable. 412 of the stars are found in the Argentine General Catalogue, and the comparison of the plans of the two catalogues shows small systematic variations in both R. A. and Declination, which was to be expected, as the zero stars used at Cincinnati all lie within the zone, and their places have been derived from various catalogues, not including that of the American Nautical Almanac (which is the basis of the Argentine General Catalogue), nor the Argentine General Catalogue itself.

Variable Stars.

This branch of Astronomy has received great impetus in the last few years. At present the Director of the Harvard Observatory is engaged upon an Index of all known observations of variable stars, published and unpublished. Catalogues of variables have been published (1) by Mr. Chandler of Harvard, in Gould's *Astronomical Journal*, viii., 81; and (2) by Mr. Gore, in the *Proc. Roy. Irish Academy*. Two new variables were discovered during the past year by Mr. Espin of Wolsingham. Professor Safarik announces in the *Ast. Nach.*, No. 2874, the discovery by

himself of no less than 17 new variables. The number of observers engaged in systematic observations of variables is now quite large.

Schiaparelli's Observations of Double Stars.

The distinguished Director of the Royal Observatory of Milan has published the measures of 465 double stars made with the Merz 8-inch refractor in the decade 1875–1885.

The catalogue is divided into four parts: the first part, by far the largest, is devoted to objects in the Dorpat Catalogue; the second to objects in the Poulkova Catalogue; the third to Mr. Burnham's double stars; the fourth to miscellaneous objects. The total number of observations is very large.

The catalogues which embody the results of the observations are preceded by an introduction of great importance, describing the instrument and micrometer, investigating the accidental and systematic errors, giving comparisons with Dembowski, and special notes; the whole forming a work of the highest importance in this branch of Astronomy.

Astronomical Photography.

The actual work of photographing the heavens, as agreed at the Astrophotographic Congress held in Paris in 1887, cannot be begun till the whole of the instruments are ready and the definitive plan of work settled. It is intended to hold a meeting of the Permanent Committee in 1890 for this definitive settlement of the working programme; by that time it is contemplated that all the instruments will have been erected and enough photographs taken to enable this programme to be settled.

Application has been made by the National Observatory of the United States to Congress for the necessary funds to provide instruments &c. to enable it to join in the work, and it is probable that one or two more observatories in America may also join.

The Permanent Committee of the Astrophotographic Congress has been most actively employed in discussing the various matters relating to the making of the chart of the heavens by photography, and has already published two parts of the "Bulletin," containing in the first number, memoirs on the mounting and orientation of the plates, by Dr. Gill; on the application of photography to the micrometric measurement of stars, by M. Thiele; on the influence of exposure on the position of the image, by M. Scheiner; and some correspondence, with a list of the observatories, numbering thirteen, that had up to that date joined in the work.

In the second part Dr. Vogel gives a communication on the

construction of the "reseaux de repère" and the deformation of the sensitive film. Professor Kapteyn contributes a memoir on the parallactic measurement of the plates, and there are other interesting letters and papers, including a brief but important note by MM. Henry, on the extent of the field of the negatives they have taken at the Paris Observatory. They think that a circular field of 3° might be counted on. This would correspond roughly to a square field 2° on the side; but even at 2° from the centre the images are fair—as the distance increases from the centre the images become regularly elliptical; at 1° 30′ from the centre the length of this ellipse is about $\frac{1}{250}$th of an inch. This result is practically what was known at the time of the Congress.

Means have been provided by our own Government for the establishment of photographic telescopes at Greenwich and at the Cape of Good Hope. There is almost a certainty that two or more instruments will be provided—but even with those already assisting, the number is sufficient to ensure the completion of the whole of the work agreed to be done.

Many of the instruments are in a forward state, and it will soon be possible to undertake the experiments that will be needed before the definitive plan already mentioned is settled.

It will be remembered that the Astrophotographic Congress passed the following resolution:—"The Congress deems it necessary that there should be a special committee devoted to other branches of astronomical photography than those relating to the chart, considering their importance and the relation which it is expedient to establish between these branches of research. This committee should place itself in communication with the committee of the chart. The Congress expresses the hope that MM. Common and Janssen would undertake the fulfilment of this wish."

MM. Common and Janssen met in London last September and in furtherance of the wish of the Congress sent the following circular letter to all those who were likely to be interested in this work:—

"In accordance with the wish expressed by the Astrophotographic Congress held at Paris last year, we are now occupied with the constitution of a committee to study the best methods of working, and to collect results obtained in celestial photography other than the photographic chart of the heavens (which is in the hands of the committee of the Congress). If you wish to take part in this work we should be glad if you would send to either of us your adhesion. Next year, when scientific congresses will be held in Paris, we intend to call together those who have thus expressed their adhesion in order to constitute a committee and examine the questions that we shall have to consider; we further ask you to let us know if you would be disposed to take part in this meeting at Paris at a time to be hereafter notified."

From English-speaking astronomers and observers the replies to this circular have been numerous and satisfactory.

The great equatorial of the Lick Observatory on Mount Hamilton has an extra glass which when placed in front of the ordinary object-glass enables the whole combination to be used as a photographic telescope—some photographs of the Moon thus taken have been sent over to this country by Professor Holden, the director of the Observatory, and they are surprisingly good. Photographs of other objects by this instrument will be looked for with interest.

Professor Pickering of Harvard College Observatory has taken photographs with an 8-inch double combination lens of about 44 inches' focal length, with exposures reaching two hours, of a portion of the sky round the great nebula in *Orion*, and finds that not only all the known nebulæ are photographed but that there is undoubted evidence of other nebulæ, twelve objects thus photographed not being in the New General Catalogue (*Mem.* R. A. S., vol. xlix. pt. I.). This has an additional interest from the fact that a close examination of a plate by the MM. Henry with three hours' exposure did not give signs of any new nebulæ. The region of sky photographed by Professor Pickering, it is true, is very rich, whilst that photographed by the MM. Henry is very poor.

Herr von Gothard, working with a 10-inch silver on glass reflector, has taken some remarkably fine photographs of the less-known nebulæ. Dr. H. C. Vogel of Potsdam gives in No. 2,854 of the *Astronomische Nachrichten* an account of some of these, with illustrations. That Herr von Gothard should have been able to obtain such exquisite photographs with such an aperture is very satisfactory, and should encourage the numerous owners of telescopes of about this size to follow his example.

The 5-foot reflector that has been under construction by Mr. Common during the last two years is completed. The effect of aperture in reducing the sizes of star discs on the photograph for a given amount of detail in the brighter portions of the nebula is shown in some recent photographs of the nebula of *Orion*, where, whilst the amount of faint detail of the surrounding portions is much greater than that given in the photographs taken in 1883, the distinct shape of the stars of the trapezium is retained.

The most successful efforts have been made by Mr. Roberts of Maghull, whose photographs of the great nebula in *Andromeda* and the nebulæ in the *Pleiades* have lately been exhibited to the Society. The latter photograph exceeds in the amount of detail it gives that taken by MM. Henry, and illustrated in the last report of the Paris Observatory, whilst the former photograph has certainly surpassed anything yet done in this line of research.

A. A. C.

The German Transit of Venus Observations.

The German Transit of Venus Commission, presided over by Dr. A. Auwers, has published vol. iii. of the Report, containing the observations made in 1882 by the four special expeditions to Hartford, Connecticut; Aiken, South Carolina; Bahia Blanca, La Plata; and Punta Arenas, in the Straits of Magellan; also those made on the Island of South Georgia (east of Cape Horn) by the members of the German Polar Expedition. The greater part of the volume is devoted to the heliometer work, which formed a special feature of the German plan of observation; but the whole of the observations made, of every class, are printed in the utmost detail, together with all that is necessary of the reductions. Vol. iv. of the Report of the Commission was published some years ago; it contains details of work done at home with the various instruments. Vols. i. and ii. have not yet appeared.

Dr. Wislicenus' Method of Determining Absolute Personal Equations in Transit Observations.

Dr. W. Wislicenus, of Strassburg, has recently published an interesting contribution to the literature of practical astronomy in a memoir entitled *Untersuchungen über den absoluten persönlichen Fehler bei Durchgangsbeobachtungen*, which contains a description of an apparatus invented by him for the determination of absolute personal equations, together with results obtained from a series of observations made with the apparatus attached to one of the transit instruments of the Strassburg Observatory. Dr. Wislicenus, fully recognising the necessity of determining personal equation with the instrument which is used in actual observation, imposed on himself three conditions as being of paramount importance:—(1) That the arrangement should be applicable to large transits or meridian circles; (2) that it should not impede the free motion of the instrument, so that determinations of personal equation may be made in the various positions in which the instrument is used for observing the heavens; (3) that the artificial star, the transits of which are to be observed, should traverse the entire field of the telescope, and in its motion should as much as possible resemble the actual motion of a real star. The artificial star in Dr. Wislicenus' apparatus is formed from the point of light which is seen in telescopes with central illumination of the field, and which proceeds from the small concave mirror which is placed on the inner surface of the objective. When viewed through a double concave lens of suitable focal length, placed in front of the eyepiece, this point of light closely resembles a moderately

bright star. The apparent motion of this artificial star across the transit threads is caused by the actual motion of the eyepiece in front of the plate carrying the threads, and is produced by an ingenious arrangement of clockwork. The automatic registration of the transits of the artificial star is effected by the passage of a platinum point, fixed to the eyepiece by a spring, across a brass plate on which are cut a series of fine lines perpendicular to the direction of motion of the eyepiece, and corresponding in number and relative distance to the transit threads. These lines are filled up with an insulating substance, so that, as the point in its motion across the plate passes one of the lines the electric current is broken and a register made. And the apparatus is to be adjusted so that the passage of the platinum point over one of the fine lines may correspond with the time when the artificial star appears to cross the corresponding transit thread.

The results obtained by Dr. Wislicenus with this apparatus are not altogether satisfactory, as, for the different rates of motion of the artificial star, he finds that his personal equation is almost a direct function of the zenith distance (being especially marked for the nadir position), thus suggesting the possibility that the observed variation with pointing of the telescope in zenith distance may really represent the varying effects of gravity on the apparatus. This is a point which ought to be further investigated in order that astronomers may determine what degree of confidence may be reposed in results obtained from the very ingenious and interesting arrangement described by Dr. Wislicenus.

A. M. W. D.

Improvements in the Methods of controlling the Driving-Clocks of Equatorials.

It is well known that Sir Howard Grubb has been for many years gradually perfecting Dr. Gill's and his own methods of controlling the driving-clocks of large equatorials, with the special object of enabling long exposures to be given to celestial photographs without the extremely tedious eye-pointing. Sir Howard Grubb has explained his methods to the Society; but in the minutes of the proceedings of the meeting of the Institution of Mechanical Engineers in Dublin, for 1888, July 31, he describes his latest improvements in considerable detail.

Papers read before the Society from March 1888 *to February* 1889.

1888.

Mar. 9. Ephemeris of the satellites of *Uranus*, 1888. A. Marth.

On invisible stars of perceptible actinic power. R. de Kövesligethy.

Telegraphic determination of the longitude of Haiphong. W. Doberck.

The total lunar eclipse of January 28, 1888, observed at the Dunsink Observatory. A. A. Rambaut.

Occultations of stars observed at the Liverpool Observatory, Bidston, Birkenhead, during the total eclipse of the Moon, 1888, January 28. J. Hartnup.

Total eclipse of the Moon, 1888, January 28. Rev. S. J. Perry.

Total eclipse of the Moon, 1888, January 28. W. F. Denning.

The lunar eclipse of 1888, January 28–29. Admiral Sir E. Ommanney.

Observations of double stars. W. Doberck.

Occultations observed at Harrow during the total eclipse of the Moon, 1888, January 28. Lieut.-Col. G. L. Tupman.

The total eclipse of the Moon, 1888, January 28. T. W. Backhouse.

On the orbit of 70 (*p*) *Ophiuchi*. J. E. Gore.

Observations of the variable star S (10) *Sagittæ*. J. E. Gore.

Orbit of the double star λ *Ophiuchi*. Professor S. Glasenapp.

Southern double stars. Rev. S. J. Johnson.

Occultations of stars during the total eclipse of the Moon, 1888, January 28, observed at the Armagh Observatory. J. L. E. Dreyer.

Ephemeris for physical observations of the Moon for the nine lunations from April 12 to the end of December 1888. A. Marth.

Photographs of the total lunar eclipse of 1888, January 28. Wm. Peck.

Observations of stars made at Glasgow Observatory in connection with the total eclipse of the Moon of 1888, January 28. Professor R. Grant.

Observations of stars occulted by the Moon during the eclipse of 1888, January 28, made at the University Observatory, Oxford. Professor C. Pritchard.

Observations of occultations of stars made at the Radcliffe Observatory, Oxford, during the total lunar eclipse of 1888, January 28. E. J. Stone.

April 13. An improved centering tube for reflecting telescopes. E. Crossley.

The Numerical Lunar Theory (extract from a letter to Mr. Knobel). Sir G. B. Airy.

Comet *Sawerthal* 1888 (extract from a letter to Mr. Knobel). David Gill.

On the occultations of Döllen's list of stars, observed at the Royal Observatory, Cape of Good Hope, during the total eclipse of the Moon, 1888, January 28. David Gill.

The total solar eclipse of 1889, January 1, in California; probable meteorological conditions at that time. Professor E. S. Holden.

The new southern comet. Observations made at Grahamstown, Cape of Good Hope. L. A. Eddie.

On the difference of longitude between Mr. Tebbutt's Observatory, Windsor, New South Wales, and the Government Observatories at Sydney and Melbourne. J. Tebbutt.

Sun-spots: their maximum and minimum periods, and their zones of greatest frequency. W. A. Ashe.

Note on *Mars*. R. A. Proctor.

Note on meteoric cosmogony. R. A. Proctor.

Observations of Comet *a* 1888 (Sawerthal), made at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

Observations of Comet *a* 1888. J. Tebbutt.

Sextant observations of Comet *a* 1888. Capt. J. Clarke.

May 11. Observation of the occultation of *Venus* by the Moon, 1888, March 9. J. Tebbutt.

Occultations of stars observed during the lunar eclipse of 1888, January 28. E. Nevill.

Observations of *Sappho* made at the Cambridge Observatory with the Northumberland equatorial and square-bar micrometer. A. Graham.

Observations of Comet *a* (Sawerthal) 1888, made at Launceston, Tasmania. A. B. Biggs.

Sextant observations of Comet *a* 1888, extracted from the meteorological log kept on board the barque "Atlantic." Captain R. Belding.

On the condition that in a double-image micrometer the value of a revolution of the micrometer screw be independent of the accommodation of the eye. Professor J. A. C. Oudemans.

Observations of the spectrum of Comet *a* 1888 (Sawerthal), made at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

Observations of Comet *a* 1888 (Sawerthal), made at the Radcliffe Observatory, Oxford. Communicated by E. J. Stone.

Observations of Comet *a* 1888 (Sawerthal), made at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

A discussion of Greenwich observations of north polar distance with reference to the position of the ecliptic, and an annual variation in the value of the co-latitude. W. G. Thackeray.

The positions for 1750·0 and proper motions of 154 stars south of −29° declination, deduced from a revision of Powalky's reduction of the star places of Lacaille's Astronomiæ Fundamenta. A. M. W. Downing.

Remarks on Sir G. B. Airy's Numerical Lunar Theory. Professor J. C. Adams.

Note on a simple method of applying electrical control to the driving clock of an equatorial. A. C. Ranyard.

Note on the total solar eclipse of 1889, December 21–22. J. R. Hind.

June 8. New arrangement of electrical control for driving clocks of equatorials. Sir H. Grubb.

Observations of Comet *a* 1888, made at Windsor, New South Wales. J. Tebbutt.

Observations of *Sappho* (80). Professor C. H. F. Peters.

Note on the Glasgow Star Catalogue. Professor R. Grant.

Description of a new observatory for a 3-foot reflector. E. Crossley.

Physical observations of *Saturn* in 1888. T. G. Elger.

On a large prime number. Sir G. B. Airy.

Observations of Comet *a* 1888 (Sawerthal), made at the Radcliffe Observatory, Oxford. Communicated by E. J. Stone.

Note on Comet Sawerthal. Dr. L. Becker.

Observations of Comet *a* 1888 (Sawerthal), made at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

Note on the visible spectrum of the great nebula in *Orion*. Dr. R. Copeland.

Nov. 9. Observations and elements of Comet Sawerthal, made at the Adelaide Observatory. Communicated by C. Todd.

Observation of the occultation of *Saturn* by the Moon, 1888, June 13. J. Tebbutt.

The ring nebula in *Lyra*. Professor E. S. Holden.

Observations of nebulæ at the Lick Observatory. Professor E. S. Holden and J. M. Schaeberle.

Results of observations of *Sappho* (80), made at the National Astronomical Observatory, Tacubaya, Mexico. Communicated by the secretaries.

Ephemeris of the satellite of *Neptune*, 1888–89. A. Marth.

Ephemerides of the satellites of *Saturn*, 1888–89. A. Marth.

Sextant observations of Comet *a* 1888 (Sawerthal), made on board the ship "Alcester." Captain L. C. Dart.

Observations of *Sappho* (80), made with the south equatorial and dark field filar micrometer, at the Melbourne Observatory. Communicated by R. L. J. Ellery.

Results of micrometric comparisons of *Jupiter* and *β' Scorpii* in May 1888. J. Tebbutt.

Height of a Perseid fireball. W. F. Denning.

Note on the occultation of *χ Orionis*, October 24, 1888. Rev. A. Freeman.

On an instrument for measuring the positions and magnitudes of stars on photographs, and for engraving them on metal plates. Isaac Roberts.

Results of recent investigations of stellar parallax made at the University Observatory, Oxford. Professor C. Pritchard.

On a compensating pendulum. R. Inwards.

On the spectra of R *Cygni* and *Mira Ceti*, and some stars with probably similar spectra. Rev. T. E. Espin.

Ephemerides for satellites of *Saturn*, 1888–89 (concluded). A. Marth.

Ephemeris for physical observations of the Moon, 1889, January 1 to April 1. A. Marth.

Observations of Comet *a* 1888 (Sawerthal), made at the Radcliffe Observatory, Oxford. Communicated by E. J. Stone.

A table of the positions of observatories, with constants useful in correcting extra-meridian observations for parallax. Lieut.-Gen. J. F. Tennant.

Observations of Comet *e* 1888 (Barnard), made at Stonyhurst College Observatory. Rev. W. J. Crofton.

Observations of occultations of stars by the Moon taken at Stonyhurst. Rev. S. J. Perry.

Observations of *Jupiter's* satellites made at the Stonyhurst Observatory. Rev. S. J. Perry.

Dec. 14. Observations of comets made at the Orwell Park Observatory in the years 1887–88. J. I. Plummer.

Observations of Comet *a* 1888 (Sawerthal) and *e* 1888 (Barnard), made at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

Photographs of the nebulæ M 31, *h* 44, and *h* 51 *Andromedæ*, and M 27 *Vulpeculæ*. Isaac Roberts.

On the determination of errors of graduation without cumulative error, and the application of the method to the scales of the Cape heliometer. David Gill.

Height of a Leonid fireball. W. F. Denning.

Photographs of the red end of the solar spectrum, from the line D to the line A. F. McClean.

On the retrogradation of the plane of *Saturn's* ring and of those of his satellites whose orbits coincide with that plane. Professor J. A. C. Oudemans.

Ephemeris for physical observations of *Jupiter*, 1889. A. Marth.

Note on the spectrum of Comet *e* 1888 (Barnard, September 2). Dr. R. Copeland.

Note on the values of the constants for the new Dearborn Observatory. Lieut.-Gen. J. F. Tennant.

Observations of Comet Barnard (1888, September 2), made at the Radcliffe Observatory, Oxford. E. J. Stone.

Note on an apparatus for correcting the driving of the motor clock of large equatorials for long photographic exposures. A. A. Common.

1889.

Jan. 11. Étoiles filantes de la période du 7–11 Août 1886, observées en Italie. F. Denza.

Photographs of the nebulæ in the *Pleiades* and in *Andromeda*. Isaac Roberts.

On methods of printing stellar charts from photographic negatives. Isaac Roberts.

The surface of the Sun in 1888. Rev. S. J. Perry.

Spectroscopic results for the motions of stars in the line of sight obtained at the Royal Observatory, Greenwich, in the year 1888. No. XII. Communicated by the Astronomer Royal.

Observations of occultations of stars by the Moon, and of phenomena of *Jupiter's* satellites, made in the year 1888, at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

Observations of Comet *e* 1888, with the transit circle, made at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

Ephemeris of the satellites of *Uranus*, 1889. A. Marth.

Observations of the Moon made at the Radcliffe Observatory, Oxford, during the year 1888, and a comparison of the results with the tabular places from Hansen's Lunar Tables. E. J. Stone.

Note on observations of nebulæ spectra at Hurstside Observatory. A. Taylor.

Ephemeris for physical observations of the Moon, 1889, April 1 to June 30. A. Marth.

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ADDRESS

Delivered by the President, Mr. W. H. M. Christie, on presenting the Gold Medal of the Society to M. M. Lœwy.

It is now my pleasing duty to lay before you the grounds on which the Council have awarded the Gold Medal to M. Maurice Lœwy for his invention of the Equatorial coudé, of a new method of determining the constant of aberration, and for his other astronomical researches.

On examining the series of memoirs in which M. Lœwy has set forth his new methods of astronomical research, we are at once impressed by the originality of conception which characterises all his ideas, and by the thoroughness with which he has worked out the details necessary for the practical application of his new methods of observation. Observational astronomy has for many years past proceeded on such well-defined lines, that we have not unnaturally come to look rather to improvements of detail than to the introduction of new instruments for the advancement of our knowledge. It is, therefore, a matter of great satisfaction to find that M. Lœwy has placed at our disposal various methods of observation based on entirely new principles, and calculated to give astronomers improved and quite independent means of attacking several of the most important problems in our science.

The first of these new instruments with which I will deal is the Equatorial coudé.

It was in the year 1871 that M. Lœwy proposed his new form of equatorial, to which the name of "Equatorial coudé" has been given, and M. Delaunay, then director of the Paris Observatory, was so struck with the value of the principle, that he arranged for the construction of an instrument on this plan. M. Delaunay's death, however, interrupted the work, and the first Equatorial coudé, having an object-glass of $0^{m}{\cdot}27$, or about $10\frac{5}{8}$ inches aperture, was not completed till the year 1882. The success of this instrument was so marked that its value could not fail to be recognised, and it was not long before the construction of several larger equatorials on the same principle was commenced. At the present time six Equatorial coudés have been completed, and four of these are already mounted and in

regular use at the observatories of Paris, Lyons, Besançon and Algiers. The other two are intended for the observatories of Paris and Vienna.

In principle the Equatorial coudé may be described as an adaptation of the form of transit instrument with axial view to the requirements of an equatorial, by the addition of a plane mirror, inclined at 45°, outside the object-glass, this mirror being capable of rotation about the axis of the telescope, so as to reflect into the latter the rays from any object in a perpendicular plane. The axis of the instrument is mounted as a polar axis between two piers, the telescope being broken at a right angle near the lower pivot, so that the rays from the object-glass are reflected by an internal mirror up the polar axis to the hollow upper pivot, where the image is formed. The rotation of the outer mirror thus brings into the field the image of any object in the hour-circle perpendicular to the object-end of the telescope, and by the rotation of the polar axis, as in an ordinary equatorial, the telescope is directed to any hour-angle. The declination-axis in the Equatorial coudé is the axis of the object end of the telescope about which the outer mirror turns, and the declination-circle placed at the eye-end, in the same plane with the hour-circle, is connected with the axis of the outer mirror by gearing, so that the observer at the stationary eyepiece has both the hour and declination circles immediately under his eye. He can thus direct the instrument to any object without moving from his chair, and his observations are made under the most favourable conditions for his own comfort, similar to those under which the microscope is used by the student of natural history. The observing room, which may be artificially warmed, is quite separated from the object-glass, and other external parts of the instrument. These latter are protected from the weather by a suitable hut, which can be rolled away on rails before observing, so that the optical parts of the equatorial are in the open air under the best conditions for establishing an equilibrium of temperature.

The importance of obtaining the favourable conditions for observation secured by M Lœwy's Equatorial coudé has long been recognised, and various attempts have been made to enable the observer to command any part of the sky without changing his position. In 1858 Dr. Steinheil proposed* a new method of mounting a reflector, so that the axis of the concave mirror formed the polar axis, the rays from a star being reflected down the axis to the concave mirror by a plane mirror, which could be rotated about a declination axis and a polar axis. The observer looked down the polar axis through a hole in the plane mirror, but with this arrangement he could not observe stars much north of the equator unless the plane mirror were made very large, and the range of the equatorial was thus very restricted. A more ex-

* *Astron. Nachrichten*, No. 1138, *Monthly Notices*, vol. xix. p 56.

tended range might be obtained by interchanging the concave and plane mirrors, so that the observer would look up in the direction of the pole; but the concave mirror and its support would block out the view of the region near the pole, and of all the sky below the pole. Sir H. Grubb has applied the same principle to the construction of a siderostatic refractor.

As compared with Dr. Steinheil's form the Equatorial coudé possesses the great advantage of commanding every part of the sky, the arm of the telescope below the elbow being made long enough to project beyond the sides of the observing room when viewing objects near the meridian.

The siderostat of Foucault, though useful for many purposes, is open to the same objection as Dr. Steinheil's, of not permitting of a view of every part of the sky; and there is the further difficulty that the apparent direction of the diurnal motion is continually changing. In the Equatorial coudé this direction changes with the declination, but M. Lœwy has now arranged that the micrometer is turned with the declination circle, and is thus always set to the zero of position angle.

The success obtained by M. Lœwy in the construction of the Equatorial coudé is due to the following circumstances:—

1. The absence of flexure in the mirrors, which are made much thicker than usual.
2. The more perfect achromatism secured by the greater focal length which this form of mounting allows of.

The first condition was established by careful experiment, which showed that in order to avoid deformation by flexure the thickness of a mirror should be between $\frac{1}{5}$ and $\frac{1}{6}$ of the diameter instead of $\frac{1}{9}$ or $\frac{1}{10}$ as had been usual hitherto.

As regards achromatism M. Lœwy urges that, in order to be able to see better with a larger object-glass, the achromatism must be made more perfect, and that, therefore, the ratio of focal length to aperture must increase with the aperture in order to diminish the effect of the secondary spectrum.

Notwithstanding the two reflections, the definition obtained with the Equatorial coudé appears to be very good, the components of ω *Leonis*, distant only $0''{\cdot}5$, having been separated with the Paris instrument which has an object-glass of $0^{m}{\cdot}27$, or about $10\frac{5}{8}$ inches. With one of the new instruments of $0^{m}{\cdot}31$, or $12\frac{1}{4}$ inches aperture, M. Trépied at Algiers easily divided γ^{2} *Andromedæ*. The loss of light by the two reflections from silvered mirrors is computed by M. Lœwy at only 12 per cent. and it would seem that it is at any rate very small, as successful observations of a minor planet of 13·5 magnitude were obtained with the Paris instrument as well as of very faint nebulæ and comets. The comet 1885 *d* (Fabry) was discovered with this instrument.

One of the objects which M. Lœwy had in view in planning

his Equatorial coudé was to obtain greater stability than is attainable with ordinary equatorials, and to make the measurement of large angular distances possible. The form of mounting of the Equatorial coudé seems peculiarly adapted to give great stability, provided the fixity of the mirrors in their cells can be secured, and this is a condition to which M. Lœwy has given special attention. Each mirror rests in its cell on thick felt or flannel, and is held by three clips, which are just brought into contact with it when in the horizontal position, as tested by the disappearance of the least trace of light between the clip and its reflected image. This adjustment being made for the horizontal position, in which the weight of the mirror has its full effect, perfect contact between the mirror and its clips will be maintained in all positions.

M. Lœwy, in conjunction with M. P. Puiseux, has investigated very completely the theory of the instrumental adjustments of the Equatorial coudé, including the effect of flexure of the polar axis and of the telescope arm, and has shown the relation of his formulæ to those for ordinary equatorials. He arrives at the two following conditions of optical adjustment as sufficient for astronomical purposes:—

1. The axis of the telescope arm should be perpendicular to the polar axis.
2. The interior mirror should reflect to the centre of the field a ray entering the telescope along the axis of the arm, supposed to be perpendicular to the polar axis.

The discussion of the instrumental errors of the Paris instrument, partly by astronomical observations, and partly by means of a collimator attached to the mounting of the exterior mirror, shows a very satisfactory accordance in the determinations on different days, and in the result the instrumental errors were found to be very small, the largest amounting only to $23''$. The coefficients of flexure are, however, rather larger quantities, being $91''$ and $53''$ for the polar axis and telescope arm respectively, as found by means of the collimator. It may be expected that in the new instruments the effects of flexure would be very much less, as important improvements have been made in their mechanical construction.

It is not a little remarkable that the first instrument made on this new principle should have given such excellent results, both optically and mechanically, and its success is evidence of the thoroughness with which M. Lœwy has worked out his idea, and of the skill with which MM. Henry and M. Gauthier have respectively carried out the optical and mechanical portions of the instrument.

I now pass on to M. Lœwy's new method of determining the constant of aberration. It is hardly necessary to insist on the importance of this constant, not only for obtaining the true positions of the stars, but, in a higher degree, for the determina-

tion of the solar parallax by means of the velocity of light. It must be admitted that the nine independent determinations of the constant of aberration made at Pulkowa with three different instruments show a satisfactory accordance, but in the opinion of M. Nyrén, who has published the latest researches on the subject, none of these can be asserted to be free from systematic error. M. Nyrén's definitive value is 20″·492, exceeding by 0″·047 W. Struve's original value, which has hitherto been generally used by astronomers. Under these circumstances M. Lœwy's method, which is based on differential measures with an equatorial, constitutes a new departure of great value in astronomy of precision, and its value is enhanced by the circumstance that it is also applicable to the determination of the constant and law of refraction.

The principle of M. Lœwy's method is the measurement of the angular distance between two stars by means of a double mirror, formed by silvering two faces of a large prism of glass, and placed in front of the object-glass of an equatorial. The double mirror is capable of rotation about the axis of the telescope, so that by reflection from the two silvered surfaces the images of two stars in different parts of the sky may be brought into the field side by side, and the distance between them measured in the direction of the common plane of reflection. In his memoir on the determination of refraction by the new method, M. Lœwy proves that the projection of the distance between the two images on the trace of the common plane of reflection is independent of the rotation of the equatorial, of any movements of the double mirror, and of the displacement of the images by the diurnal motion, when the observation is not made rigorously in the plane of reflection.

M. Lœwy's exposition of his method of determining the constant of aberration is contained in a series of communications made to the French Académie des Sciences and published in the *Comptes Rendus*, vols. civ. and cv. In giving an account of this investigation, I will proceed at once to the general method for determining aberration, which M. Lœwy discusses after treating some special cases.

The determination of aberration requires the measurement of the distance between a pair of stars at successive epochs when the effect of aberration on the angular distance is reversed. The observations are made when the two stars have the same altitude, so that the effect of refraction is a minimum, and the comparison of the two measures gives a multiple of the constant of aberration, which is independent of all instrumental errors and also of precession and nutation, as the distance between two stars is unaffected by any movements of the earth's axis or of the ecliptic. There is the further advantage in the new method, that the effect of aberration as measured is much greater than in the ordinary methods of observation.

But the result might be affected by change of refraction or

by alteration in the angles of the double mirror resulting from thermal expansion between the two epochs of observation, and M. Lœwy has therefore imagined a general method of observation which eliminates any possible effects of the kind, as well as methods applicable to special cases which determine any changes due to refraction or expansion of the mirror.

The essence of the general method is that two pairs of stars are observed, the four stars being selected so that at the time of observation they are all simultaneously at the same altitude and that the effects of aberration on the two arcs connecting the stars of each pair are large and of opposite sign. Thus the two arcs formed respectively by the two pairs of stars are compared simultaneously both at the first and at the second epochs.

The first point for investigation is the effect of aberration on the angular distance between a given pair of stars. From the geometrical conditions M. Lœwy arrives readily at the result that the effect is proportional to the cosine of the angle between the median* of the arc and the direction of the Earth's motion.

Calling Δ the angular distance between two stars,
p the angle between the median of the arc joining them and the direction of the Earth's motion,
and k the coefficient of aberration,

the effect of aberration is given by the formula

$$d\Delta = 2k \sin \frac{\Delta}{2} \cos p.$$

It readily follows from this that the effect of aberration on the difference of the two arcs connecting two pairs of stars will be greatest when the two medians are on the same vertical circle on opposite sides of the zenith. Under these circumstances, the effect of aberration on the difference of the two arcs is equal to

$$4k \sin \frac{\Delta}{2} \sin \frac{\Delta'}{2} \cos \mathrm{L},$$

Δ' being the angular distance between the two medians, and L the angle between the direction of the Earth's motion and the line of intersection of the vertical plane through the medians with the horizon. Thus the effect is proportional to the cosine of this angle, and the greatest effect will be obtained when the vertical plane of the medians, the ecliptic and the horizon intersect in the same line, and the observations are made at the two epochs six months apart when the direction of the Earth's motion coincides with this line, L having the values 0° and 180° at the two epochs respectively. In that case the effect of aberration on the difference of the two arcs has opposite signs at the two

* The median is the line bisecting the angle between the directions of the two stars.

epochs, and the comparison of the two sets of measures of the two arcs gives

$$E = 8k \sin\frac{\Delta}{2} \sin\frac{\Delta'}{2},$$

where E is the difference of the two measures of difference of arcs at the first and second epochs respectively.

The next point for consideration is the choice of the angle for the double mirror, the angular distance (Δ) between the two stars in each pair being necessarily twice this angle. Obviously the altitude at which the observation of the four stars is made diminishes as Δ and Δ' increase, and M. Lœwy shows that the maximum effect at any given altitude is obtained by making $\Delta' = \Delta$, or the angular distance between the medians the same as that between the two stars in each pair. He then gives the following table of the altitude h and of the effect of aberration $\frac{E}{k}$ corresponding to the several values of the angle of the double mirror α :—

α	30°	35°	40°	45°	50°	55°	60°
h	48° 35′	42° 9′	35° 58′	30° 0′	24° 24′	19° 12′	14° 29′
$\frac{E}{k}$	2·0	2·6	3·3	4·0	4·7	5·4	6·0

M. Lœwy concludes that the angle of the double mirror should not exceed 50°, and he considers that on the whole it would be well to make it 45°, so that the altitude of the stars would be 30°, and the angular distance for each pair 90°. Under these conditions observations made at two epochs six months apart would give as the quantity measured four times the constant of aberration, while the ordinary methods of observation only give at the maximum a measure of twice the constant. But in order to avoid daylight observations M. Lœwy thinks it would be advisable to be satisfied with a slightly smaller coefficient of k (the constant of aberration), say three instead of four, which would reduce the interval between the two epochs to about ninety-eight days, and by combining the observations in the first five weeks with those in the last five, a series of equations would be obtained in which the coefficient of k would vary from three to one, the mean value being about two. All the observations could then be made in the night hours.

Besides the general method of observation just described, M. Lœwy has, as already mentioned, devised two methods applicable to special cases which are well suited to give independent determinations of the constant of aberration.

The first method consists in the observation of two pairs of stars, of which one pair gives at the end of two or three months the measure of twice the constant of aberration, and the other, completely unaffected by aberration, exhibits the effect of tem-

perature on the double mirror. The first pair of stars should be in the neighbourhood of the ecliptic; the second pair is, as will be seen from geometrical considerations, to be chosen so that the latitudes of the two stars are the same, and that their longitudes differ by 180°, in order that the arc joining them may be unaffected by aberration.

This method is, however, not applicable at observatories within 20° of the equator, and on this account, as well as to give another independent determination of the constant of aberration, M. Lœwy proposes a second method according to which the angular distance of a single pair of stars near the ecliptic is to be observed for a period of three months or longer, the measures in the first and last twenty-five days of the period being used to determine the aberration, and those in the intermediate forty days to deduce the effect of temperature on the double mirror.

The question of the adjustment of the double mirror remains to be mentioned. This must be mounted so as to turn about the optical axis, and this axis should coincide nearly with the axis of figure. The effects of any movements of the double mirror will then be as follow:—

1. In turning round the axis of figure the two images are displaced in opposite directions, but perpendicularly to the trace of the common plane of reflection.
2. In turning round an axis in this plane and perpendicular to the axis of figure the two images move in the same direction perpendicularly to the trace of the plane of reflection.
3. If the double mirror turns about an axis perpendicular to the plane of reflection, the two images move along the trace without changing their relative distance.

Reference has already been made to the applicability of M. Lœwy's new method to the determination of refraction at various altitudes. This was, in fact, the immediate object which M. Lœwy had in view when he devised the method, and his investigation of the conditions of the problem was communicated to the French Académie des Sciences early in 1886, the year before he published his memoir on aberration.

In his series of papers on the determination of refraction published in the *Comptes Rendus*, vol. cii., M. Lœwy first gives a method for determining the constant of refraction, the law according to which refraction varies with the altitude being known. A pair of stars is observed when refraction has its maximum effect on their angular distance, and again when the effect of refraction is a minimum. For the maximum effect one of the stars must be on the horizon. and the other in the same vertical circle with it, while for the minimum both stars must be at the same altitude. M. Lœwy then finds that the greatest variation of refraction will be obtained with an angle of 30° for the double mirror, but as with this there would be (for

the latitude of Paris) a minimum interval of $6^h\ 35^m$ between the two epochs of observation, he prefers to take an angle of 45° for the double mirror, sacrificing only 15″ in the effect of refraction, while reducing the interval between the observations to $4^h\ 44^m$. This is the minimum value of the interval found by selecting the pair of stars so that their common zenith distance at the second epoch is equal to the angle of the double mirror, or half the angular distance between the two stars.

The geometrical conditions thus found by M. Lœwy to give the maximum effect in the minimum interval of time between the observations may be somewhat modified in practice, provided the angular distance between the stars does not differ by more than a few minutes from twice the angle of the double mirror. M. Lœwy has thus been able to find some twenty pairs of bright stars suitable for the determination of refraction by this method. In its practical form the method consists in the measurement of the angular distance between a pair of stars 90° apart when one of the stars is near the horizon and the other near the zenith, and again when both the stars are at about the same altitude. It is not necessary that at the former epoch the low star should be very near the horizon, for, as M. Lœwy points out, observations may be advantageously continued till the altitude is nearly 20°, and thus the constant of refraction may be determined from observations which are practically unaffected by any uncertainty in the law of refraction.

It will readily be understood that the observation of the low star may be made either when it is rising or when it is setting. In the latter case the observation of the stars at equal altitude would precede that for which one of the stars is setting. By combining the observations of two pairs of stars chosen so that the first pair is rising when the effect of refraction on the second is a minimum, and that the first pair is at the minimum when the second pair is setting, the influence of any change in the angle of the double mirror will be eliminated by taking the mean of the two determinations, while the difference of these will give four times the change of angle in the interval, thus affording a precise determination of any such change, if it exists.

Various other methods are proposed by M. Lœwy for determining the refraction at any altitude without assuming its law of variation. These methods, however, appear to involve practical difficulties, as they either assume the absence of irregular variations in the refraction at an altitude of 10°, or require the construction of several double mirrors with different angles. They may be considered as supplementing the first method; and they are of interest as giving a direct measure of refraction independently of any theory.

The practical determination of the constants of aberration and refraction by the new method is being carried out by M. Lœwy and M. P. Puiseux with the Equatorial coudé of the Paris

Observatory, and the series of observations made during the past twelve months confirms in the most satisfactory manner the theoretical conclusions. M. Lœwy finds that the variations of the distances are really free from systematic errors, and he considers that the constant of refraction will be more accurately determined from a few nights' observations with his new method than from years of meridian observations.

In conclusion I can only allude in the briefest terms to the other important researches for which astronomers are indebted to M. Lœwy. The following is a summary of the other new methods of instrumental research which M. Lœwy has devised in the last few years :—

1. A method for determining the flexure of transit-circles at various zenith distances by means of an optical apparatus inserted in the central cube. This has been used to find the flexure of two transit-circles at the Paris Observatory, the absolute values of the flexure for the two ends of the telescope and for the axis being independently determined.

2. A method for obtaining the latitude without making use of the declinations of fundamental stars.

3. A general method for determining right ascensions without relying on assumed right ascensions of polar stars.

4. A method for finding on each night the absolute declinations of stars without the necessity for observations of polar stars at upper and lower transit.

5. Methods for determining directly the two co-ordinates of polar stars without a previous investigation of the instrumental errors.

All these methods except the first are based on the observation of close circumpolar stars in R.A. and N.P.D. out of the meridian at various points of the circles described by them. Conjugate observations either of a single star or of a pair of stars having the same N.P.D. are made with a transit-circle, having a field of view of 2°, at equal intervals (about two hours) before and after meridian passage or before and after passage over the hour-circle of 6^h east or west. The special methods of observation are developed in a series of communications to the French Académie des Sciences made in the years 1883 and 1885, and during the last two years M. Renan has applied these new methods to a determination of the latitude of the Paris Observatory based on 80 very accurate results.

The account which I have given of M. Lœwy's inventions and researches is necessarily very imperfect, and I have had to pass over many points of interest in the application of his methods. But I trust that the summary I have made will at any rate suffice to show the very high importance of M. Lœwy's labours, and that they fully deserve the recognition which is to-

day given to them, whether we have regard to the originality of the methods or to the value of the results which are to be obtained from them.

The President then, delivering the Medal to the Foreign Secretary, addressed him in the following terms :—

Dr. Huggins,—In transmitting this medal to M. Lœwy I would ask you to assure him of our very high appreciation of the services which he has rendered to Astronomy by the invention of his Equatorial coudé and of his new methods for determining important astronomical elements, and to express our hope that his life and strength may long be spared to enable him to continue the successful application of the instrumental means he has devised for the advancement of our science. We deeply regret that we are deprived of his presence to-day, through the effects of a serious accident, but trust that he will ere long be completely restored in health and vigour.

The meeting then proceeded to the election of the Officers and Council for the ensuing year, when the following Fellows were elected:—

President.

W. H. M. Christie, Esq., M.A., F.R.S., Astronomer Royal.

Vice-Presidents.

J. C. Adams, Esq., M.A., Sc.D., LL.D., D.C.L., F.R.S., Lowndean Professor of Astronomy, Cambridge.
J. W. L. Glaisher, Esq., M.A., Sc.D., F.R.S.
E. J. Stone, Esq., M.A., F.R.S., Radcliffe Observer.
Lieut.-Gen. J. F. Tennant, R.E., C.I.E., F.R.S.

Treasurer.

A. A. Common, Esq., F.R.S.

Secretaries.

A. M. W. Downing, Esq., M.A.
E. B. Knobel, Esq.

Foreign Secretary.

William Huggins, Esq., LL.D., D.C.L., F.R.S.

Council.

Capt. W. de W. Abney, C.B., R.E., F.R.S.
Arthur Cayley, Esq., M.A., Sc.D., LL.D., D.C.L., F.R.S., Sadlerian Professor of Pure Mathematics, Cambridge.
Hon. Sir James Cockle, M.A., F.R.S.
Warren de la Rue, Esq., M.A., Ph.D., D.C.L., F.R.S.
Edwin Dunkin, Esq., F.R.S.
George Knott, Esq., B.A., LL.B.
Capt. William Noble.
Rev. S. J. Perry, D.Sc., F.R.S.
W. E. Plummer, Esq.
E. J. Spitta, Esq.
Lieut.-Col. G. L. Tupman, R.M.A.
H. H. Turner, Esq., M.A., B.Sc.